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A case for spatial planning to manage the growing threat of wildfire in New Zealand peri-urban landscapes

A thesis
submitted in partial fulfilment
of the requirements for the Degree of
Masters of Landscape Architecture

at
Lincoln University
by
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Lincoln University
2018

Abstract of a thesis submitted in partial fulfilment of the
requirements for the Degree of Masters of Landscape Architecture

A case for Spatial Planning to manage wildfire in New Zealand Peri-Urban
landscapes

by

Steffan Krabberger

The 2017 Christchurch Port Hills Fires were an expression of increasing peri-urban wildfire threat in New Zealand. Internationally, traditional response management of wildfire threat has been complemented by place-based and pre-emptive social and spatial strategies. The formal recovery plans for the Port Hills Fires highlight the emerging role of social programmes but a distinct lack of spatial peri-urban planning in New Zealand wildfire management practice and research. Spatial dynamics have had a clear impact on the nature of the Port Hills peri-urban wildfire threat, yet the current recovery process largely reinstates the spatial patterns which heightened the likelihood, scale and impact of the 2017 fires. The spatial trajectories being followed in Port Hills will likely lead to a future where this wildfire threat is further heightened, highlighting the opportunity for spatial planning to intervene now and create a more resilient peri-urban community and landscape.

Keywords: Spatial planning, wildfire threat, wildfire management, alternative futures, historic inquiry, peri-urban, Port Hills, New Zealand

Acknowledgements

First and foremost, I would like to express gratitude to my supervisors Professors Simon Swaffield and Wendy McWilliam, you have been both supportive and instrumentally critical in your guidance and assistance throughout my thesis.

Thanks to the School of Landscape Architecture both staff and students, who make such a vital research environment. Thanks to my fellow Masters students for your help and guidance throughout the thesis process and its premise.

Finally, to my family, friends and especially Rose, for your valued and necessary input, support, love and patience.

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Figure 1 // The Port Hills after the 2017 fires

Chapter 1 Introduction

Context

Wildfire is an unplanned and uncontrolled fire (Majorhazi & Hansford, 2011; Wooten, 2003). When it occurs in a peri-urban area, it poses a significant threat to human life, homes and infrastructure (T. Paveglio, Carroll, & Jakes, 2010; Rundel & King, 2001). Peri urban wildfire risk in these areas (defined here as the probability of fuels within a landscape undergoing sustained burning (Syphard, Massada, Butsic, & Keeley, 2013)) tends to be high due to their multiple ignition sources and large amounts of fuel to support sustained ignition (Rundel & King, 2001). With climate change, wildfire threat in many areas is expected to increase, particularly with continued peri-urban expansion (Gill, Stephens, & Cary, 2013; A. Smith et al., 2016). In efforts to manage this threat, strategies have been developed for high-threat peri-urban areas internationally, involving a combination of land management, social development and more recently, spatial planning measures (e.g., Paveglio & Edgeley, 2017; Syphard et al., 2013; Smith et al., 2016).

Problem statement

In New Zealand, peri-urban wildfire threat is similarly increasing (G. Pearce, Langer, Harrison, & Hart, 2014; H. G. Pearce et al., 2005). Management of this wildfire threat is largely focused on land management and social development strategies, with a distinct lack of spatial planning strategies. This is despite land-use changes such as the transition from rural to lifestyle blocks being recognised as deeply affect peri-urban New Zealand Wildfire Risk (Hart & Langer, 2011). Spatial planning is here defined as a strategic approach to planning, which is distinct for being strongly embedded in spatial context, developed through collaboration with multiple parties, and for being evidentially based (Gardner-Hopkins & Fairgray, 2011)

Spatial planning can manage wildfire by pre-emptively arranging risks, hazards and values in patterns which remove or mitigate wildfire threat (Syphard et al., 2013), and through co-development can affect social development and land management (Bhandary & Muller, 2009).

Internationally, wildfire risk management involving spatial planning is being translated into legislation. For example in the United States the Healthy Forest Restoration Act 2003 advocates for the development of localised Community Wildfire Protection Plans (CWPPs) as a way of *“clarifying and refining their priorities for the protection of life, property and critical infrastructure in the wildland-urban interface”* (T. Paveglio, Carroll, & Jakes, 2008). In New Zealand, the Fire and Emergency New Zealand Act 2017 focuses on land management and some social development prerogatives. The Resource Management Act 1991 gives a more focused spatial planning mandate, obligating local authorities to have an *“awareness and understanding”* of wildfire (as a natural

hazard), and to “control the use, development and protection of land for managing the avoidance or mitigation of Natural Hazards” (New Zealand Government, 1991). However, the response to the recent 2017 Port Hills fires have demonstrated the tendency of local governing bodies to focus on prompt and restorative recovery (Gill, 2005), forgoing the opportunity to manage future wildfire threat through spatial planning.

Research question and objectives

The institutional neglect of spatial planning as a means to manage wildfire threat in New Zealand peri-urban landscapes shapes the underlying question of this thesis, which is: *‘What impact does spatial landscape change have upon wildfire threat in New Zealand peri-urban landscapes, and furthermore what is the potential and implications for spatial planning to manage this threat?’*

The following objectives guide the thesis towards answering this two-part question.

Objective A) Review literature to determine and evaluate the nature of peri-urban wildfire threat management, and compare New Zealand approaches with international approaches.

Objective B) Investigate the role and influences of past landscape change in a case-study example of the Port Hills (as an example of a New Zealand peri-urban landscape), evaluating how this has affected wildfire threat in the past and more recently with the 2017 Port Hills fires.

Objective C) Explore the capacity of spatial planning to manage this wildfire threat in the Port Hills, comparing this against continuing with current spatial planning directions.

Objective D) Assess the opportunities and implications for including wildfire management within peri-urban spatial planning practice in New Zealand.

Research Strategy and thesis structure

The research strategy is an interpretive research (Deming & Swaffield, 2011) case study, involving alternative futures. This allows for specific landscape changes to be evaluated in the past, present and future (Deming & Swaffield, 2011; Stahlschmidt, 2017). Three alternative futures are developed: two futures explore likely planning and landscape change trajectories (one statutory and one more ‘bottom-up’), and these are evaluated against a third alternative future, which uses best practice international wildfire spatial planning strategies applied to the Port Hills case study

The thesis structure reflects this process. Chapter Three reviews international and New Zealand wildfire literature, detailing the nature of wildfire threat and its management and evaluating the role

of spatial planning and its applicability to New Zealand. Chapter Four is an historical inquiry that details landscape change and planning trajectories throughout the Port Hills history, evaluating correlations with wildfire threat. Chapter Five details the relationship between landscape change and wildfire threat during the 2017 Port Hills Fires, and then evaluates the 2017 Port Hills fires recovery for its management of historical wildfire threat patterns and against international standards of wildfire management. Chapter Six details and evaluates the three alternative futures, and Chapter Seven makes a case for spatial planning to manage wildfire in New Zealand Peri-Urban landscapes. This is achieved by first clarifying the impact of landscape change and spatial planning have upon wildfire threat in New Zealand peri-urban landscapes, and secondly clarifies the opportunities and implications for spatial planning to manage this threat.

Case Study Selection

The Christchurch Port Hills were chosen as the case-study site. They have an expanding Peri-Urban component (Christchurch City Council, 2014b), and according to Wildfire Threat Analysis undertaken in 2010/2011 they have a 'very high wildfire threat risk-profile' (Christchurch City Council, 2014b). The large wildfire events of February 2017 exemplify the wildfire threat in the area, and give opportunity for evaluating the recovery from a specific event.

Grant Pearce, in his 2014 article '*Describing Wildfire Prone Areas in the New Zealand context*' identifies three key spatial factors which are affecting wildfire threat in New Zealand, climate change, peri urban landscape changes, and expansion of the recreation estate. The case study site exhibits these features, extending from the seaward to the inland sides of the Port Hills, and to the North-eastern extent of Raupaki Track, and to the southwest extent of Early Valley. This is shown below in Figure 2, and again in chapter Six in Figure 37, where site and its land uses and covers are further detailed. The case study site largely¹ covers the extent of the February 2017 Fires, and includes a wide variety of land uses and land covers (e.g pastoral farming with scrubby pasture, reserves with regenerating bush, recreation/public access, residential lifestyle blocks, ...).

The Port Hills are also considered to be of high natural and amenity value (Boffa Miskell, 2015), which means there is a complex mosaic of landscape values throughout the area which could be affected by wildfire. Given that Wildfire Risk is season-dependent, the evaluation of the Case-Study

¹ The case-study site has excluded the Selwyn District Council jurisdiction in which the fire took place, due to a lack of available land-use information.

site and development of the alternative futures are considered within the summer season, during the hot, dry and drought period (Gill, 2005, p. 67; G. Pearce, Teeling, & Clifford, 2013).

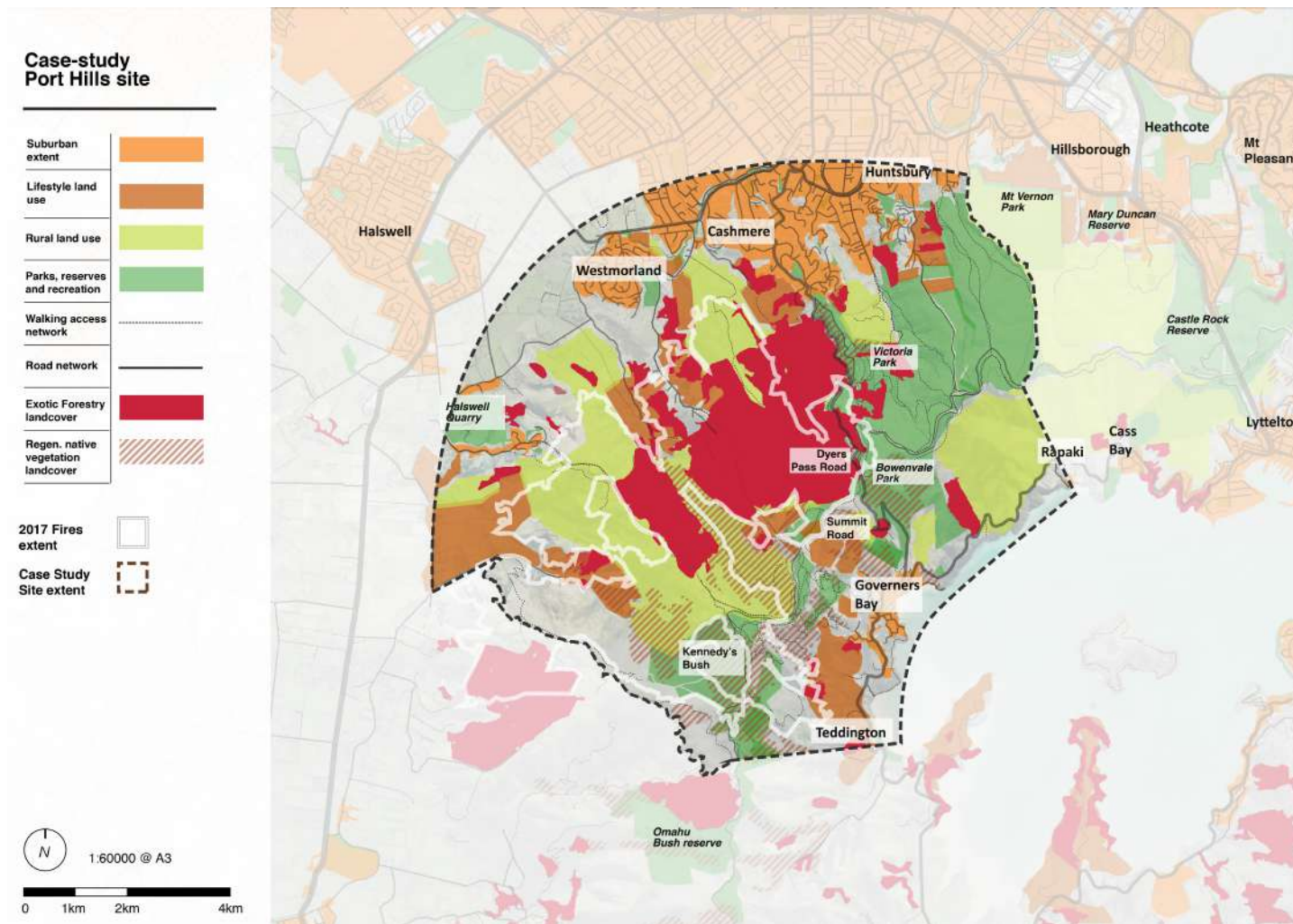


Figure 2 // Case-study site with land uses prior to the 2017 Port Hills fire, and with the extent of the 2017 Port Hills Fires shown with a bold white outline

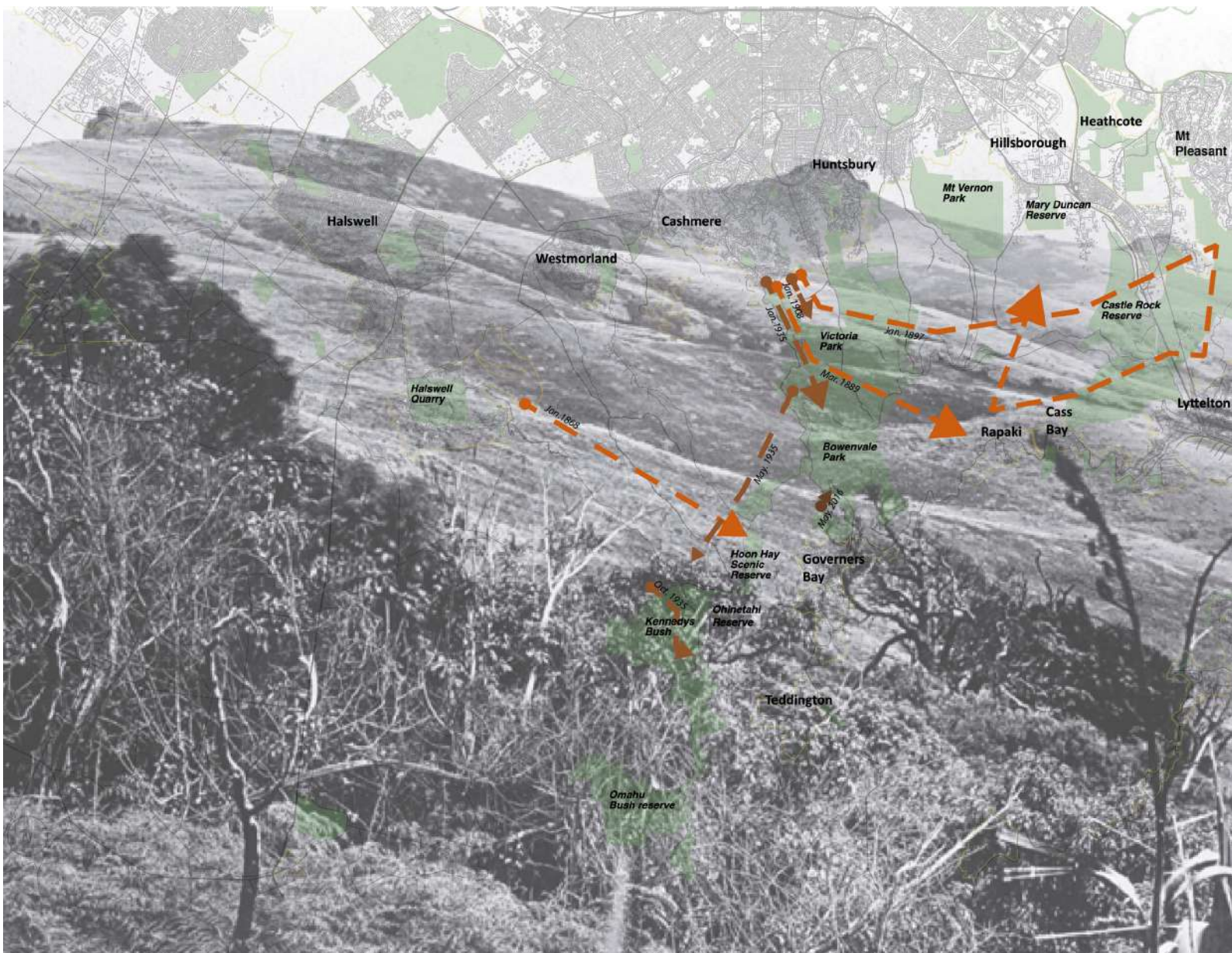


Figure 3 // Historic Photo of Coppers Knob with open pasture and pockets of bush (unknown, 1920), overlaid with the Port Hills historic fire map showing the frequency of fire events in the area (Chapter 4)

Chapter 2 Research methods

This chapter details the specific methods used for Chapters Four and Six, and then illustrates how the all the methods interrelate throughout the thesis.

Historical inquiry

The role of the historical inquiry is to clarify landscape change and planning trajectories throughout the Port Hills history, evaluating correlations with wildfire threat. There are three established methods of historical inquiry: retrospective, chronological and retrogressive (Stahlschmidt, 2017). Retrospective and chronological methods expand understandings or questions of the present, while the retrogressive method looks to reconstruct a past using present understandings. Within this thesis, retrospective and chronological methods are used to determine landscape change and planning trajectories in Chapter Four, while the retrogressive method is used to evaluate the alternative futures in Chapter Six.

The retrospective method involves tracing the genesis of present issues within wildfire-implicated landscape elements, such as the *Pinus radiata* plantations in the present Port Hills landscape. Alternatively, landscape elements identified in historic fires can be traced further back in history. These specific issues and their histories are then collated as a chronological sequence along the theme of wildfire threat and its management within the Port Hills landscape. This establishes the planning and landscape change trajectories, forming a basis for the alternative futures in Chapter Six.

The three methods are further illustrated in Figure 4 below, which uses a graph of relevant information per decade to demonstrate the path of inquiry across past, present and future for each method.

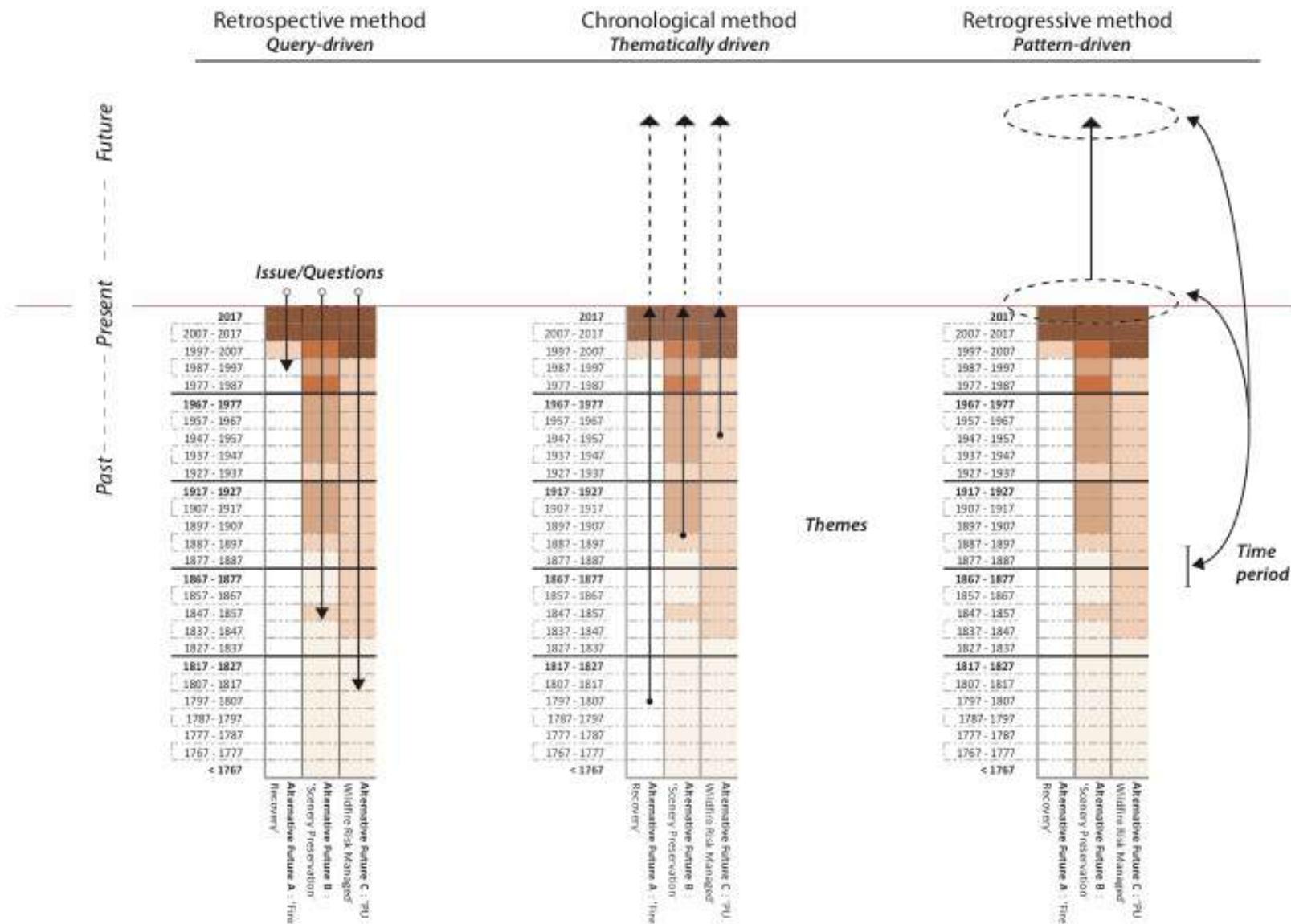


Figure 4 // Methods of historical inquiry applied to basic density mapping

Alternative Futures

Normative alternative futures are a form of predictive modelling involving the analysis and comparison of possible futures for an area (Deming & Swaffield, 2011). In a spatial application, the comparison of possible scenarios with each other and with the present scenario gives insight into the implications of current spatial decisions and trajectories (Corry & Nassauer, 2004). Chapter six explores three alternative futures which are:

Alternative Future A - Statutory Planning: Follows the largely restorative mandate of the 2017 Port Hills Recovery Plan, this alternative future follows a scenario of pre-fire statutory planning.

Alternative Future B – Scenic Preservation: Follows the prevalent community imperative of Scenic Preservation. Its mandate to preserve and protect the nature, beauty and open character of the Port Hills has had significant spatial effects, and shapes the second alternative future.

Alternative Future C – Spatial Wildfire Management: The third alternative applies international-sourced spatial planning strategies for wildfire management.

Alternative Futures A and B are linear projections (Deming & Swaffield, 2011), where landscape changes have already been projected, or follow a planning trajectory. In contrast to this, Alternative Future C requires significant design input to apply the international strategies into the site.

The alternative futures are compared by aligning and evaluation their effects on the Port Hills landscape. The Port Hills landscape is defined through a series of landscape categories, with the effects of each alternative future detailed for the various categories, before the alternative futures are compared in their entirety. Alternative C is a spatial application of international wildfire management in the Port Hills, and therefore forms the normative basis for the evaluation of the other linear alternative futures, highlighting the wildfire threat implications of current decision making and trajectories.

This normative evaluation is then extended by using retrogressive historical inquiry to compare historic wildfire patterns with the alternative futures and the case study landscape immediately prior to the 2017 wildfires.



Figure 5 // Port Hill fires photographed from below (Younger, 2017)

Chapter 3 Literature review; peri-urban wildfire management

The literature review gives context and theoretical grounding to the thesis, and is structured with five sections. First the term wildfire is defined, along with peri-urbanism and its wildfire implications. From these definitions, dimensions of peri-urban wildfire threat are explained, followed by the phases and types of strategies involved in its management. These understandings structure the overview of International and New Zealand peri-urban wildfire management, which highlights gaps in New Zealand practice. The gap this thesis focuses on is spatial planning. Later within the thesis in Chapter 6, specific spatial planning methods are imagined within the case-study as alternative future A, exploring their potential for managing wildfire threat in New Zealand peri-urban landscapes.

Peri-Urban Wildfire

Wildfire is an unplanned and uncontrolled fire with a significant non-structural component (be it forest, scrub or grass fire), including planned fires that have gotten out of control (Majorhazi & Hansford, 2011; Wooten, 2003). Wildfire, also called 'Bushfire' in Australia, is internationally recognised as a natural phenomenon which can both support and disrupt ecological processes and cultural practices (Bardsley, Weber, Robinson, Moskwa, & Bardsley, 2015; Champ, Brooks, & Williams, 2012; A. Smith et al., 2016). However, its uncontrolled occurrence within Peri-urban landscapes threaten a wide range of values, including human life, utilities, Culture, Forestry, Property, Aesthetics, Recreation, Agriculture, Biodiversity and Horticulture (Bardsley et al., 2015; Gill et al., 2013; Majorhazi & Hansford, 2011).

Peri-Urban areas are landscapes in transition from urban to rural (Parliamentary Commissioner for the Environment, 2001), and are also referred to within Wildfire Literature as the WUI (Wildland Urban Interface) and RUI (Rural Urban Interface) (G. Pearce et al., 2014). Peri-Urban areas have two relevant typologies: 'Interface', which involves an urban area and a wildland area meeting at a boundary, and 'Intermix' where structures are scattered through wildland (non-structural) areas (Bhandary & Muller, 2009). A third typology of 'Island/Occluded' exist, where wildland areas are scattered through urban areas, however this is less relevant to the Wildfire Risk in Peri-Urban areas (Koebele et al., 2014). While each of these Peri-Urban patterns entail different landscapes and therefore different Wildfire Management, all three affect Wildfire Threat through the interlaced combination of Fuels to burn, ignition sources, and values to be effected by fire (Butsic, Syphard, Keeley, & Bar-Massada, 2017, p. 162). Furthermore, Peri-Urban Wildfire threat is unique from other fire threat and needs to be specifically managed (T. B. Paveglio, Nielsen-Pincus, Abrams, & Moseley, 2017; G. Pearce & Langer, 2017; A. Smith et al., 2016).

Wildfire Threat

Best practice wildlife management strategies are place specific. A first step to developing or adapting a strategy is to determine the wildfire threat of the area of concern. This includes an analysis of what the threat is currently (Majorhazi & Hansford, 2011; UNISDR, 2017), and can also include what it could be in the future under different land use development scenarios and risk management strategies (Miller & Ager, 2013). The factors that determine the threat include: the level of wildfire risk (i.e. probability of the structures within a landscape undergoing sustained burning), the level of hazard (i.e. the character and patterns of a landscape that contribute to the intensity, rate of movement and spread of a fire (e.g., micro-climate, landforms and available fuels)), and the number of people, resources and values placed on resources that are threatened by a wildfire (Majorhazi & Hansford, 2011; Wooten, 2003). Increases in any of these factors increase the level of threat (Figure 1).

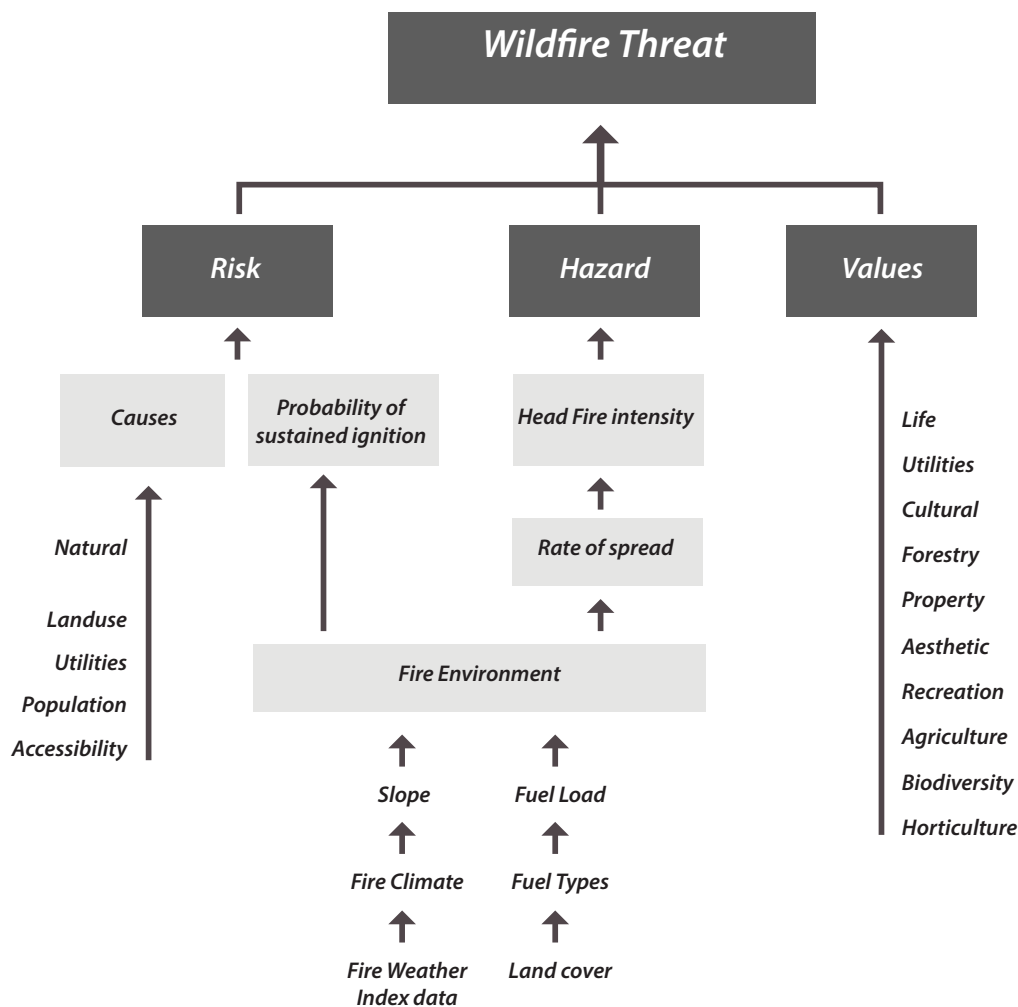


Figure 6 // Factors that determine the level of wildfire threat within periurban areas, adapted from (Majorhazi & Hansford, 2011)

Wildfire Threat is being augmented by Peri-urban expansion, Climate change and growing Recreation networks (Bowman et al., 2011; Gill et al., 2013; P. J. Jakes & Langer, 2012; T. Paveglio et al., 2008; A. Smith et al., 2016).

This is perpetuating Wildfire issues in historically prone areas such as the western United States, Australia and the Mediterranean basin, but is also seeing Wildfire Threat become more relevant in less-prone areas such as New Zealand (Champ et al., 2012; P. J. Jakes, Kelly, & Langer, 2010; A. Smith et al., 2016). As in New Zealand, perceptions of low threat in less prone areas results in a low uptake of threat-management measures, which further increases Wildfire Threat (P. J. Jakes et al., 2010; H. G. Pearce et al., 2005). The growth of Peri-Urban Wildfire Threat is driving Management measures to be more effective by considering all dimensions of Wildfire Threat at various scales, and in the short and long term (Gill, 2005).

Peri-urban wildfire management

Wildfire management goals

Goals for wildfire risk management are developed for threat factors depending on the phase of management (Figure 2), whether it is occurring before, during or after a wildfire event (Gill, 2005; A. Smith et al., 2016). Goals are chosen depending on the phase of management according to the threat factors of concern. A matrix linking wildfire management phases, dimensions and goals (Figure Two) suggests that the best time to manage fires is well in advance to their occurrence. Reducing all factors that determine the level of threat can only be achieved through pre-planning. As the time cycle of a fire event advances, management options become more limited. The readiness, or capacity to reduce the level of hazard or values damaged by the fire (by residents or fire response staff), and the speed at which this capacity is deployed (i.e. response) can both be increased before and during the fire, but it is too late to reduce the probability of a fire occurring. Finally, recovery works across all three dimensions to either restore or improve the risk, hazard and values of an area, with the option of improvement being the basis of entering into a cycle of Wildfire Management (G. Pearce & Anderson, 2008).

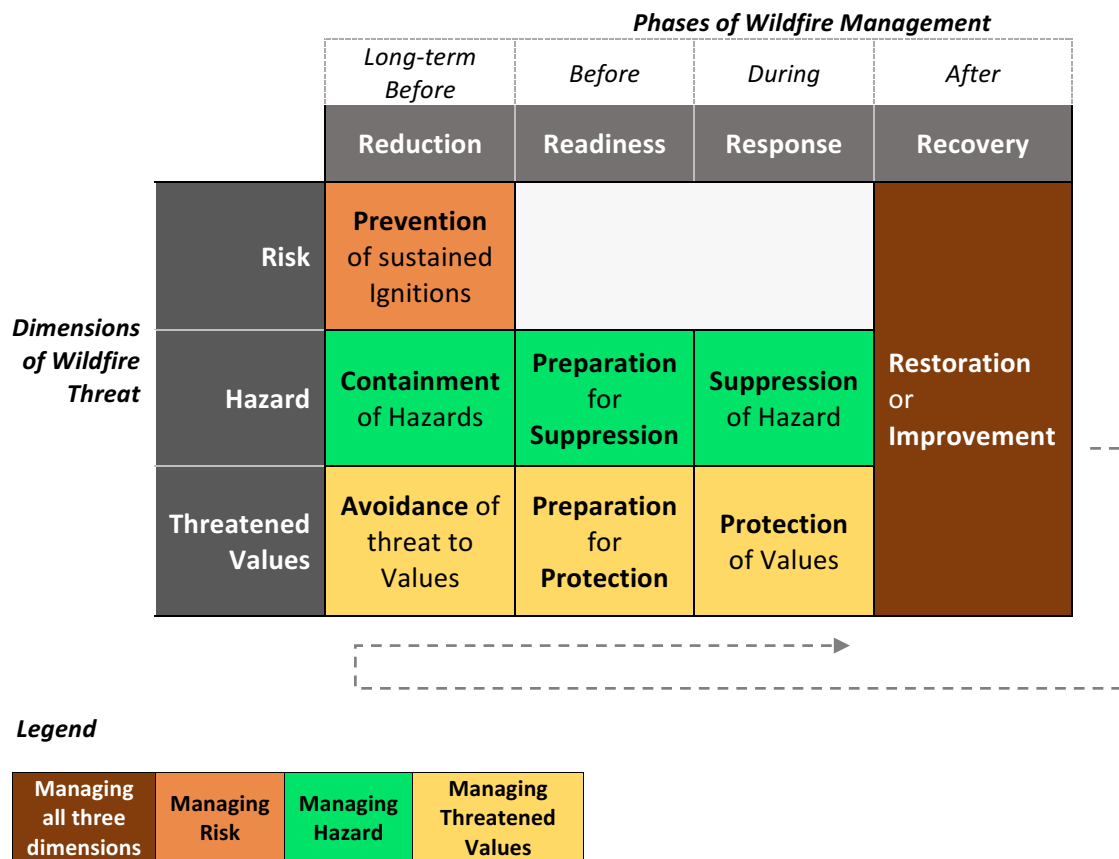


Figure 7 // Wildfire management goals

Wildfire management strategies

A variety of strategies have emerged which address these goals, and are often categorised by the stakeholders who undertake them (Champ et al., 2012; Gill, 2005; Gill et al., 2013; A. Smith et al., 2016), however the overall wildfire management structure is simplified if these are seen as isolated strategies. These strategies are social development, spatial planning and land management. Each strategy involves a range of different methods, which in turn are realised through a range of actions. For example, one method within land management is fuel management, which through actions such as prescribed burning or mechanical pruning works to contain hazards, prevent sustained ignitions, prepare-for and protect values, and prepare-for and suppress hazards (Fernandes & Botelho, 2003; Furlaud, Williamson, & Bowman, 2018; Gill, 2005; Schwab, Meck, & Simone, 2005). This example and the overall classification of wildfire management is shown below in Figure 8. The strategies are then discussed in the next section.

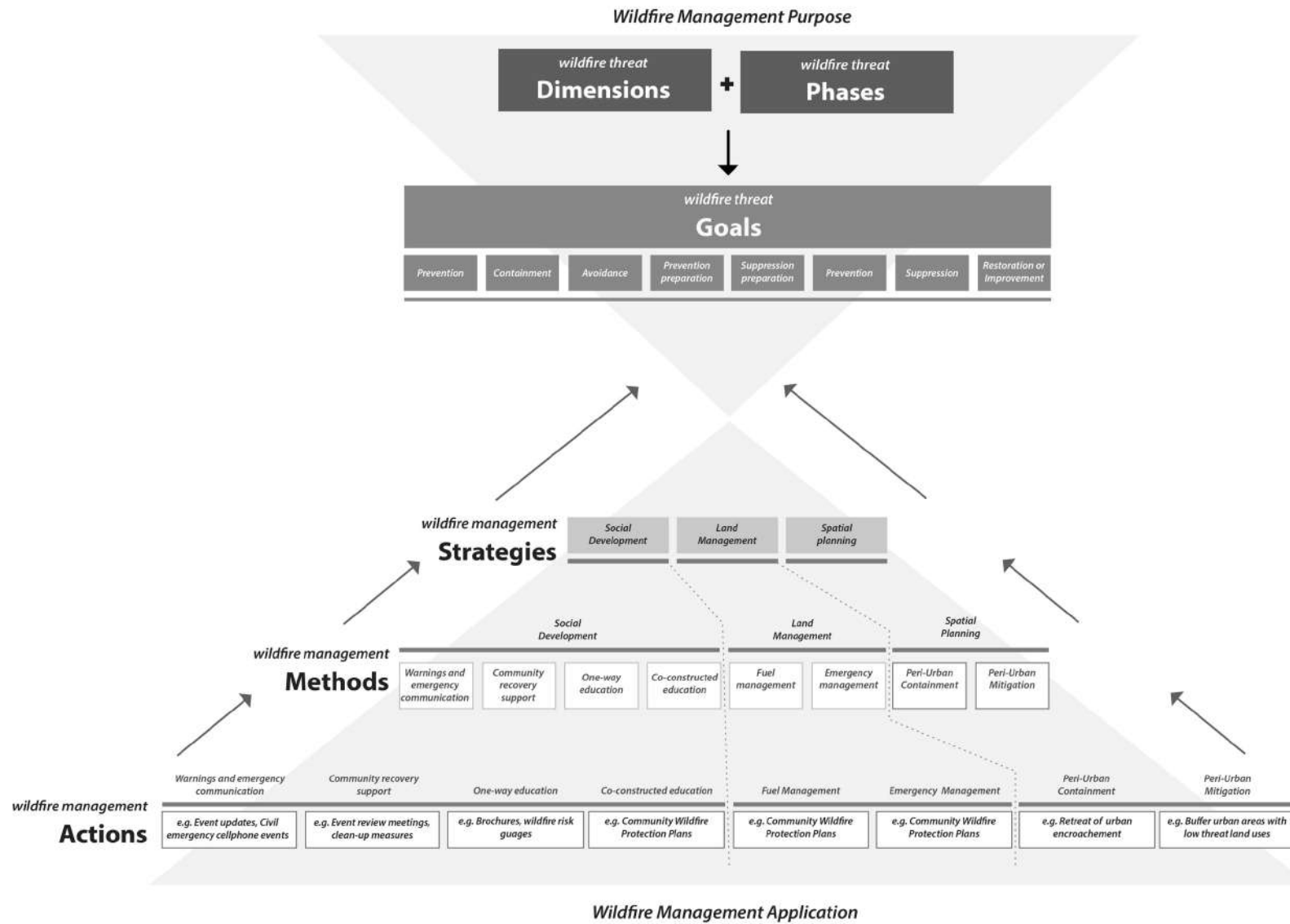


Figure 8 // Wildfire management framework

Strategies of peri-urban wildfire management

Social Development Strategies

There are four main methods that contribute to a social development strategy for wildfire management: warnings and emergency communication, community recovery support, one-way education, and co-constructed education.

Warnings and emergency communication and community recovery support have long been key components of wildfire management internationally, and have steadily improved with technological developments, and the formalisation of communication hierarchies and support networks (Bones, 2005; Bridge, 2010; Gill, 2005). This is reflected within New Zealand, where early warnings and emergency communication, community recovery support, along with one-way education have been widely undertaken to reflect international standards, and continue to be developed (FENZ, 2017b; Kelly, 2005; Langer & McGee, 2017; H. G. Pearce et al., 2005; SCION, 2015). However, co-constructed education is still an emerging method in New Zealand (P. J. Jakes & Langer, 2012; Kelly, 2005).

This in part reflects International trends, where educating communities about wildfire threat has been historically undertaken through one-way education with actions such as brochures and fire risk gauges which concentrate on the strategies of prevention and both types of readiness (Gill, 2005; McCaffrey, Toman, Stidham, & Shindler, 2012; Toman, Shindler, & Brunson, 2006). In the last two decades, co-constructed education has emerged as the preferred method for disseminating information on wildfire threat and its management (Champ et al., 2012; McCaffrey et al., 2012; T. Paveglio & Edgeley, 2017; Toman et al., 2006). This is because it effectively achieves more forward-thinking goals of prevention, containment, preparing-for and protecting values, preparing for suppression and improvement-based recovery.

Co-constructed education initially focused primarily on preparedness for protection and suppression, educating through measures such as public meetings, guided tours and Interpretation centres (McCaffrey et al., 2012; Toman et al., 2006). This led to the effective uptake of land management methods such as defensible space around homes and improved accessibility for suppression (T. Paveglio & Edgeley, 2017). As a collaborative process, the feedback of these actions and localised knowledge is being used to refine wildfire threat analysis, structure and realise land management, and ground planning processes, such as the identification of this strategic evacuation point shown in Figure 9 below (McCaffrey et al., 2012).



Figure 9 // Shelter point sign in Lillydale, near Melbourne, Australia (Skipworth, 2018)

Co-constructed education has evolved to focus more on long term prevention and containment objectives, as well as improvement-based recovery goals. This has occurred through improved Readiness, which by increasing awareness also reduced human ignition (McCaffrey et al., 2012; T. Paveglio et al., 2010). Furthermore, by empowering Land Management around homes and communities, available fuels are reduced and therefore Ignition and Hazard are further contained (P. J. Jakes & Langer, 2012; T. Paveglio et al., 2010). Lastly, by reducing the threat and impact of Wildfires, the need for Restoration is lessened, and the success of amelioration is reinforced (McCaffrey et al., 2012; T. Paveglio et al., 2010). Comprehension and experience of successful wildfire management helps with allocation of recovery assistance to affect the same or better outcomes (Edgeley & Paveglio, 2016).

Co-constructed education has also been found to effectively work towards protection itself with 'stay and defend or leave early' approaches', though this has brought about issues of knowing when to evacuate, and what qualifications are needed to protect valuable resources from wildfire (Gill, 2005).

Land Management strategies

A land-management strategy typically contains one or both key methods, which are 'fuel management' and 'emergency management'.

Fuel management involves the extent, layout and materiality of any natural and human resources, which in a wildfire event are likely to act as fuels (Moritz et al., 2014). This involves actions such as designing a house with fire-retardant materials or removing property vegetation to make defensible-space, and is largely applied to prevention, containment and both types of readiness, along with recovery (Graham, McCaffrey, & Jain, 2004). Historically, a large component of fuel management has consisted of prescribed burning, but with the effects of escaped burns being much higher in peri-urban areas, other forms of vegetation management has developed, such as mechanical pruning and specified grazing (Champ et al., 2012). The use of fire-retardant materials in and around buildings have similarly progressed with extensive technological developments (Calkin, Cohen, Finney, & Thompson, 2013). New Zealand are working towards similar standards with Fuel Management (FENZ, 2017b).

Strategic fuel management through measures such as defensible space buffers and fire-breaks, can also affect a readiness, by pre-determining fuels available for a wildfire event and therefore making its behaviour more predictable and controllable for protection and suppression efforts (Graham et al., 2004). This is a growing facet of land management, especially with effective social development strategies mobilising homeowners to undertake such actions on private property (McCaffrey et al., 2012).

Emergency management involves managing wildfire events to contain hazard, and minimise the impact upon values (Gill, 2005). Emergency management has long worked to affect early suppression and restorative recovery, which has steadily become more effective with improved suppression preparation, and extensive technological developments. For example emergency management suppression sees a 95-98% success rate in the United States (Calkin et al., 2013). Generally emergency management services therefore concentrate on aggressive and early suppression, with personnel and appliances working on the ground and aurally (Gill, 2005). However, continuous aggressive and early suppression has resulting in fuel build-ups, which perpetuates wildfire threat issue and therefore has brought about a focus on improved preparation for both suppression and protection (Cohen, 2008; Houtman et al., 2013).

Protection by emergency management services utilises many of the same measures as suppression, but applies them to protecting zones or points (National Wildfire Coordinating Group, 2015).

However, the fires at this point are already at an ‘overwhelming’ scale, making protection measures costly and highly threatening to Emergency Services’ safety (Cohen, 2008). Emergency management protection can also involve the overseeing and planning of community evacuation, which depending on the degree of threat for a specific wildfire event and relevant policies for a specific area, can be enforced or voluntary (M. Taylor & Freeman, 2010).

The extensive technological and operational development is driving emergency management towards more effective suppression and protection capabilities, while tactical planning and provision/awareness of defensible space is developing readiness (Petrovic, Alderson, & Carlson, 2012; M. Taylor & Freeman, 2010). Emergency Management is also starting to leverage on local community knowledge before, during and after wildfire events (McCaffrey et al., 2012).

Overall, land management strategies as both fuel and emergency management have long been at the core of wildfire management, and continue to be technologically and strategically developed both globally and within New Zealand (FENZ, 2017b). For example, large-scale New Zealand land managers ‘The Department of Conservation’ (DOC) are showing signs of realising preventative and containment wildfire management within biodiversity and planting, as shown with the descriptive billboard for a DOC Abel Tasman Project shown below in Figure 10.

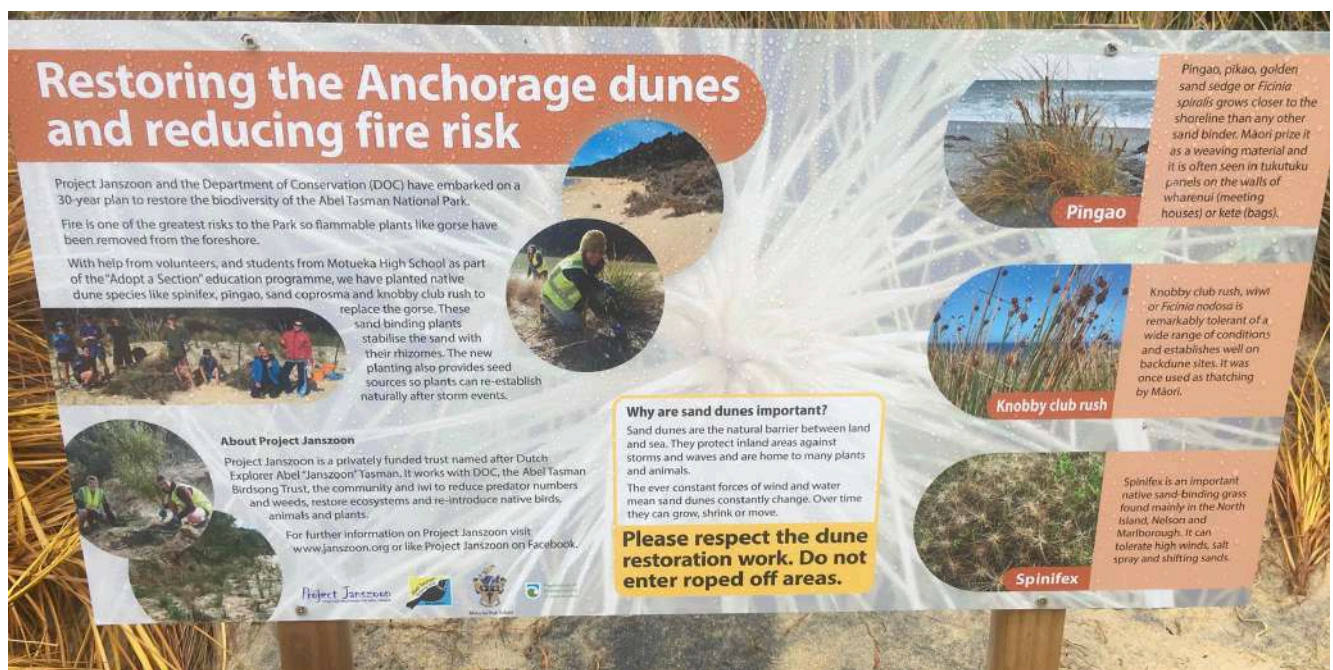


Figure 10 // Description of Planting by Land Managers in the Abel Tasman National Park, NZ

Spatial Planning Strategies

Spatial planning strategies include two key methods relevant to peri-urban wildfire management, the first is 'peri-urban containment', which works at a landscape scale to direct development away from hazardous landscapes, avoiding the creation of peri-urban landscapes (Gill, 2005; Syphard et al., 2013). The second is 'Peri-Urban Mitigation' which involves locating development within and around established peri-urban areas in places best suited to avoid, prevent, contain and protection against wildfire threat (Gill et al., 2013; A. Smith et al., 2016). Both spatial planning methods have emerged relatively recently Internationally, and are being widely recognised and applied as a key component to achieve more comprehensive management of wildfire threat (Bihari, Hamin, & Ryan, 2012; Kocher & Butsic, 2017; Syphard et al., 2013).

Spatial planning affects wildfire management by developing policy and plans which suitably arrange land-use and spatial systems to affect reduction and readiness (Gill, 2005). As a forward-looking process, spatial planning also has an ameliorative role in the recovery from wildfire (Burby, Deyle, Godschalk, & Olshansky, 2000).

Spatial planning is generally undertaken by investigating the implications between wildfire threat and past, present and future planning and management decisions (Syphard et al., 2013). These are often co-developed into spatial planning strategies (Kocher & Butsic, 2017; Syphard et al., 2013). By basing decisions on avoiding threat for communities, spatial planning need a substantiated understanding of links between peri-urban wildfire threat, land-uses, land-cover and land management functions (Syphard et al., 2013). Internationally, these links being extensively researched (Bihari et al., 2012). For example, the longer the periphery of a residential land-use area, the higher the risk of sustained ignition (Gill, 2005).

However, strategies are often less generalised than this example, as community input is now a central component of wildfire management, and requires spatial planning to be developed through collaborative/localised processes (Burby et al., 2000; Sturtevant & Jakes, 2010). Examples of spatial planning to affect wildfire management have been recorded in North America, England, Australia, Canada and throughout the Mediterranean Basin, and involve both key approaches listed above (Harris, McGee, & McFarlane, 2011; Rasker & Barrett, 2016; A. Smith et al., 2016).

Spatial planning strategies for wildfire management in New Zealand have received little to no attention, with examples isolated to comments by wildfire-affected community members that planning of land-use and development should be taking wildfire threat into consideration (Hart & Langer, 2011; Woodford, 2017).

Discussion

The relationship between the different wildfire management goals and the wildfire management strategies and their subset methods are shown below in Figure 11. The diagram summarises international best practice, as well as showing approaches used in New Zealand and in the Port Hills fires. It also notes aspects that appear to be underrepresented in NZ practice.

Overall, international wildfire management strategies are moving away from responsive goals such as aggressive suppression (Champ et al., 2012; A. Smith et al., 2016). A new focus has been emerging which couples the refinement of responsive goals with more forward-thinking reduction, readiness and recovery goals by improving social development, particularly through co-constructed education, and the integration of wildfire management into spatial planning (Penman et al., 2017; A. Smith et al., 2016). These types of approaches recognise the complexity of wildfire threat and the unavoidability of wildfires, and work to manage wildfire by considering a wide suite of wildfire causes and effects. In New Zealand, however, there is only a very limited recognition of the potential for spatial planning to contribute to peri-urban wildfire management, and no evidence was found of its application or research within a New Zealand context.

		Long-term Before			Before		During		After	Phases of Management
		Reduction			Readiness		Response		Recovery	
Strategies	Methods	Prevention of sustained Ignitions	Containment of Hazards	Avoidance of threat to Values	Preparation for Suppression	Preparation for Protection	Suppression of Hazard	Protection of Values	Restoration or Improvement	
Social Development	Warnings and Emergency Communication									
	One-way education									
	Co-constructed Education									
	Community recovery support									
Spatial Planning	Peri-Urban Containment									
	Peri-Urban Mitigation									
Land Management	Fuel Management									
	Emergency Management									

International Best Practice Wildfire Management		Emerging International Best Practice Wildfire Management		New Zealand/Port Hills Wildfire Management		Distinctly lacking Components in New Zealand practice	
Managing all three dimensions	Managing Risk	Managing Hazard	Managing Threatened Values				

Figure 11 // Relationship between the wildfire management goals and the strategies

Statutory setting for wildfire management in New Zealand

At a statutory level, the New Zealand Government recognizes 'fire' through three key documents, the Resource Management Act (1991), The Fire and Emergency New Zealand Bill (2017), and The Crown Pastoral Land Act (1998), which is not relevant to the Port Hills situation as it is directed at High Country areas.

The RMA (Resource Management Act (1991)) lays out how New Zealand should manage its Environment (Ministry for the Environment, 2015). Within the Act, '*fire*' is seen as a 'natural hazard' which is 'any atmospheric or earth or water related occurrence [...] which adversely affects or may adversely affect human life, property, or other aspects of the environment'. To this effect, the RMA requires Territorial Authorities and Regional Councils to 'undertake the control of the use of land for the purpose of [...] the avoidance or mitigation of natural hazards' (and therefore Wildfire). It also requires Local Authorities to 'keep records of natural hazards to the extent that the local authority considers appropriate for the effective discharge of its functions'. The RMA therefore requires these governing bodies to have an awareness and understanding of Wildfire Threat, and also undertake Wildfire Management.

Statutory management of Fire in New Zealand is currently in a transition period with the introduction of The Fire and Emergency New Zealand Bill (2017). This bill aims to provide a more coordinated fire and emergency service across New Zealand (The New Zealand Fire Service Commission, 2015). Previously, two governing bodies, the 'New Zealand Fire Service' and the 'National Rural Fire Authority' oversaw management within 12 enlarged rural fire districts and 26 territorial authority rural fire authorities (Fire and Emergency New Zealand, 2017). These were all amalgamated into Fire and Emergency New Zealand (FENZ) on the first of July 2017, and promises to increase the focus on Readiness and Reduction through Prevention while primarily refining the operational capacity for Suppression (FENZ, 2017b).

Conclusion

While New Zealand is overall moving towards a more comprehensive and international model of peri-urban wildfire management, spatial planning has been particularly underexplored by academics, planners and specialists. Leadership needs to be shown at a research and local governance level to develop the application of spatial planning for managing New Zealand peri-urban wildfire threat. This would allow for spatial strategies to be integrated into the expanding body of social development and land management strategies, allowing for the multi-faceted approach that is being internationally heralded as the only way to manage peri-urban wildfire (Burby et al., 2000; Buxton, Haynes, Mercer, & Butt, 2011; Gill, 2005; Gill et al., 2013; Rasker & Barrett, 2016; A. Smith et al., 2016; Syphard et al., 2013)

Furthermore, under the RMA (1991) wildfire threat must be considered when managing the use, development, and protection of natural and physical resources – a statutory obligation which is currently being fulfilled only in part.



Figure 12 // Edited version of 'Bird's eye view of Banks Peninsula and Canterbury Plains' (Smith & Anthony Limited, 1900), to show the approximate location of The Port Hills

Chapter 4 A historical inquiry of wildfire in the Port Hills



Figure 13 // Looking the Northern side of the Port Hills from above Christchurch (Wikipedia commons, 2012)

The Port Hills are a distinct geographical area which sit to the South/East of Christchurch City, rising dramatically above what is otherwise very flat city, as shown above in Figure 13. The natural and cultural development of the Port Hills has seen many phases, which have all involved differing implications for wildfire. Understanding the development of landscape elements and practices within the Port Hills along with their associated wildfire implications, enriches our understanding of Port Hills Wildfire Threat in the present and future, leading to more spatially-grounded Wildfire Management actions (A. Smith et al., 2016). These phases of history structure the chapter, and are as follows:

- 12 – 8 million years ago - Volcanic formation
- 8 million years ago – 1300 CE – Mature forest canopy cover and erosion
- 1300 – 1500 - Early Maori and the Initial burning period
- 1500 – 1850 – Maori settlement and regeneration with native scrub and tussock
- 1850 – 1900 - European settlers, native forest harvesting and scrub clearing for pasturelands
- 1850 – 1900 - European settlers, native forest harvesting, and scrub clearing for pasturelands
- 1900 – 1970 - Forming the peri-urban edge and scenic preservation
- 1970 – January 2017 - Continued peri-urbanisation, forestry and intermixed lifestyle blocks
- Statutory planning at the point of the Port Hills Fires

12 - 8 million years ago - Volcanic formation

The Port Hills were formed around 12 million years ago by the Lyttelton Volcano, as the rim of many eruptions which over many millennia have eroded down to the land-form we see today (Hampton & Cole, 2009). Volcanoes such as this are the predominant pre-human cause of fire in New Zealand, and the Port Hills are today still criss-crossed with a tapestry of volcanic remnants including dykes, domes, deep gullies and rocky outcrops, such as those shown below in Figure 14 (Christchurch City Council, 2010; Hampton & Cole, 2009; Orwin, 2008).

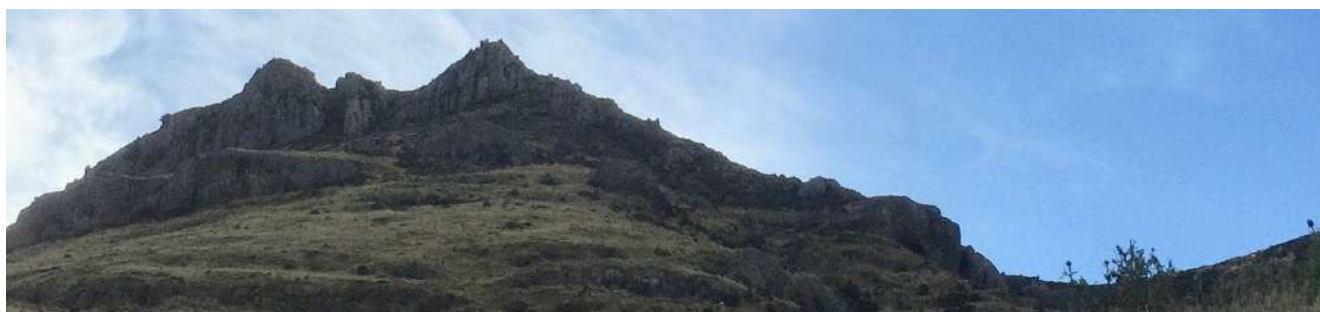


Figure 14 // Rock formations on the Port Hills, picture taken above Purau Bay

8 million Years ago - 1300 CE - Mature forest canopy cover and erosion

Aside from a lasting legacy of fire-formed geomorphology, the Port Hills prior to human arrival experienced few fires as much of the area was densely vegetated with mature podocarp forests which with their dense broadleaf habit gave little opportunity for lightning storms to cause sustained ignition (Carswell, 2017; Guild & Dudfield, 2009; Wilson, 2013). Furthermore, New Zealand indigenous vegetation has evolved to be slow to recover from fire, which strongly suggests that there were overall few fires in pre-human New Zealand (Guild & Dudfield, 2009).

1300 – 1500 - Early Maori and the intensive burning period

In 14th century when Waitaha Maori settlers first arrived in Canterbury (Dwyer, 2014), the Port Hills were largely covered with mature lowland forest, and some upper areas of mature sub-alpine forest and tussocklands (Wilson, 2013). With Maori arrival came what is known as the Initial Burning Period, an era when Maori undertook extensive clearing of indigenous forest by frequently lighting fires for moa hunting, ease of access, and croplands (Dwyer, 2014; Guild & Dudfield, 2009; Johnstone et al., 2016). A large portion of the Port Hills extensive forest-cover is thought to have been burnt during this era (Christchurch City Council, 2010; Wilson, 2013).

1500 – 1850 - Maori settlement and regeneration with native scrub and tussock

By the 16th century the Moa was extinct and the Initial Burning Period ended with the Port Hills Waitaha assimilated into Ngati Mamoe, which was in turn were assimilated into Ngai Tahu two hundred years later in the 18th century (Christchurch City Council, 2010). From the 14th Century through to when the Europeans arrived in the 19th century an estimated 30-50% of indigenous forest cover was lost on the Port Hills, predominantly through fire (Wilson, 2013).

In place of this mature forest came succession vegetation such as tussock, Kanuka and small leaved shrubs, which is much more flammable than the mature forest cover such as native podocarps (Dwyer, 2014; Johnstone et al., 2016).



Figure 15 // *The Maori Settlement of Purau Bay, Port Cooper* (Oliver, R. A., 1850)

Waitaha, Ngati Mamoe, and Ngai Tahu Port Hills settlements were located along the coastline of Te Whakaraupō (Lyttleton Harbour), and were connected throughout and across the Port Hills to the wetlands and lakes of the Canterbury Plains by a network of Mahinga Kai trails (Christchurch City Council, 2010; Orwin, 2008). This trans-Port Hills connectivity was central to the workings of the Te Whakaraupō communities, and was also crucial for European settlers in the 19th Century to be able to access the Canterbury plains from Lyttleton (Christchurch City Council, 2010).

Maori of this era have been reported to have a high awareness of wildfire threat, which likely led to actions observed elsewhere in the South Island such as early collective suppression, and watering the roof thatch in settlements (Williams, 2009). In place of mature forest came scrubby succession vegetation, which is more flammable than the mature forest cover, introducing a new and extensive hazard on the Port Hills (Dwyer, 2014; Johnstone et al., 2016).

1850 – 1900 - European settlers, native forest harvesting, and scrub clearing for pasturelands

With the 1850 landfall of European settlers in Lyttelton, the Port Hills was first observed purely as a barrier for accessing the Canterbury Plains, but were soon seen for their potential in milling (Orwin, 2008). This led to extensive deforestation of the Port Hills, and by the dawn of the 20th century only very small isolated pockets of mature forest remained amongst an open and more fire-susceptible landscape of succession vegetation (Boffa Miskell, 2007, 2015; Fogarty, 2002). The milling and mining of the Port Hills supplied the housing demands of the broader Christchurch area, however there was little settlement upon the Port Hills at this early stage (Ogilvie, 1978; Robertson, 2016). As the mature forest was steadily cleared, the Port Hills became well positioned to be converted into Farming and Horticulture to service the produce demands of the new Christchurch settlement, marking the next era in the Port Hills.



Figure 16 // Canterbury Plains - New Zealand (E. Norman, 1855)

Farming first emerged in the latter half of the 1840's with a series of Sheep Stations, the first being Mount Pleasant, which was soon joined by Cashmere, Hoon Hay, Lansdowne, Halswell and Ahuriri Stations (Ogilvie, 1978, 2000). With farming on the Port Hills, came the need to clear the succession vegetation which now densely covered the hill with scrub and tussock, a process which similar to many parts of New Zealand was undertaken through the use of fire (Guild & Dudfield, 2009; Ogilvie, 1978; Robertson, 2016). Though effective, a lack of knowledge and resources for managing this prescriptive use of fire meant that many of them got out of control (Guild & Dudfield, 2009). In the Port Hills, land clearance caused wildfires as early as 1860 (Robertson, 2016), with the remoteness and lack of fire-fighting resources making wildfire a major concern for life in the area. However, this also led to a high awareness of wildfire threat, with actions such as early collective suppression by communities was a common occurrence (Rooney, 1993; Stapylton-Smith, 2009).

However the European settlers also introduced exotic species such as gorse and broom which have a high flammability, and along with the new and expansive tracts of pasture introduced a new and seasonal hazard, especially when under-grazed (Carswell, 2017).

By 1890 these sheep stations were largely subdivided into smaller farms and horticulture (Kennelly, 1949; Ogilvie, 1978, 2000; Robertson, 2016). However, escaped clearance fires continued to be a an issue, for example in 1931 a farmers clearance fire got out of control and burnt most of Kennedy's Bush, one of the few remaining remnant forest bodies on the Port Hills (The Press, 1931). Then again, 4 years later a gorse clearing fire got out of control also not far from Kennedys Bush (The Press, 1935b). The introduction of European farming to the Port Hills saw a new wave of clearance-caused wildfires throughout Port Hills, yet this farming era also entailed extensive land-cover changes with much of the Port Hills converted to pasture (Ogilvie, 2000).

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<http://www.vcbrowne.com/Detail3.aspx?RID=PB0713&PID=232&Caller=Search>

Figure 17 // Governors Bay Wildfire, date unknown (V.C. Browne and Son)

1900 – 1970 - Forming the peri-urban edge and scenic preservation

The start of the 19th Century also saw encroaching suburban expansion around the Port Hills (Ogilvie, 1978), increasing fire risk, and several large scale wildfires were recorded around the time (Robertson, 2016; The Press, 1889, 1897).

On the northern side of the Port Hills, Cashmere was established in 1890 upon one the long ridges this characterise this side of the Port Hills. This suburb was and is a desirable congestion-removed suburb, and set the presedent for a series of similar residential suburbs which extended around the base of the Port Hills to the east of Cashmere, capitalising upon the out-looking ridges such as Huntsbury and Hillsborough. Further to the east on the Port Hills seaward/western side, similar headland suburbs evolved such as Mt Pleasant and Clifton Hill. In the valleys below, residential suburbs also emerged, however their protected micro-climates meant they also had large tracts of intensive horticulture such as in Heathcote and Avoca Valleys.



Figure 18 // Early development of Cashmere looking east over the Port Hills towards the Southern Alps (T. P. D., 1920)

As these suburbs developed, they formed a sinuating northern Port Hills peri-urban edge which laps against the Port Hills and extends up the ridgelines. The edges of these suburbs, and especially Cashmere have been the source location of many wildfires on the Port Hills, which are often then driven up and over the Port Hills by prevailing Northerly and North-Westerly winds (The Press, 1889, 1897, 1908, 1935a, 1935b).

Suburban expansion bought with it changes in rural land, remnant native forest, and public access to these areas, which in the early 20th Century fuelled the Scenic Preservation movement. The movement was comprised of a number of interest groups, which were predominantly urban-based and concerned with the preservation of accessible nature within and at the fringes of urban areas (Ministry for Culture and Heritage, 2012; Nightingale & Dingwall, 2003). The movement in the Port

Hills was figure headed by Harry Ell who, with his dream to create 'public access to a reserve covering the Port Hills' (Bellard et al., 2015), achieved a broader vision of national Scenery Preservation through his successful advocacy of the 'Scenery Preservation Act 1903' (Nightingale & Dingwall, 2003). This Act enabled hallmark acquisition and establishment of reserves in New Zealand (Ministry for Culture and Heritage, 2012), allowing Ell to secure 1200 hectares of Port Hills scenic Reserve by 1915 (Orwin, 2008). He also imagined and promoted the Summit Road that now stretches along much of the ridgeline of the Port Hills, and which along with several connecting roads such as Dyers Pass Road empowered open public access up and along the Port Hills. Harry Ell continued to expand this Scenic Preservation network until his death in 1934 (Orwin, 2008)



Figure 19 // Construction of the Summit Road near Kennedys Bush (Unknown, 1910)

The Scenic Preservation vision however continued after Harry Ell's death, largely under the guidance and influence of the Summit Road Society, a group established in 1948 by Harry Ell's grandson John Jameson (Ogilvie, 2000). The values of the Scenic Preservation Movement to preserve and protect the nature, beauty and open character of the Port Hills (Summit Road Society, 2017c) have been threatened by Wildfire, but also fuelled and caused it.

For example in 1931 Kennedys Bush was nearly entirely destroyed by wildfire which deeply affected a valued component of the Scenic Preservation network, yet this remnant native vegetation and the surround scrubby bush also fuelled the fire to continue up to the Summit Road (The Press, 1931). Native revegetating of the Port Hills by Scenic Preservation groups has involved actively planting and encouraging natural succession of vegetation, as with the 150ha Ohinetahi Bush (Summit Road Society, 2017d). This brings with it a long transitional period with more fire-prone scrubby vegetation (Fogarty, 2002), and also raises issues with stock removal which allows grasslands to be

more of hazard (P. J. Jakes & Langer, 2012; Woodford, 2017). The Summit Road and expanding public access networks has reflected nationwide trends by facilitating arson and carelessness caused fires from activities such as fireworks, car use or discarded cigarettes (Doherty, Anderson, & Pearce, 2008; Kirk-Anderson 2016; G. Pearce, 2017; The Press, 1935a).

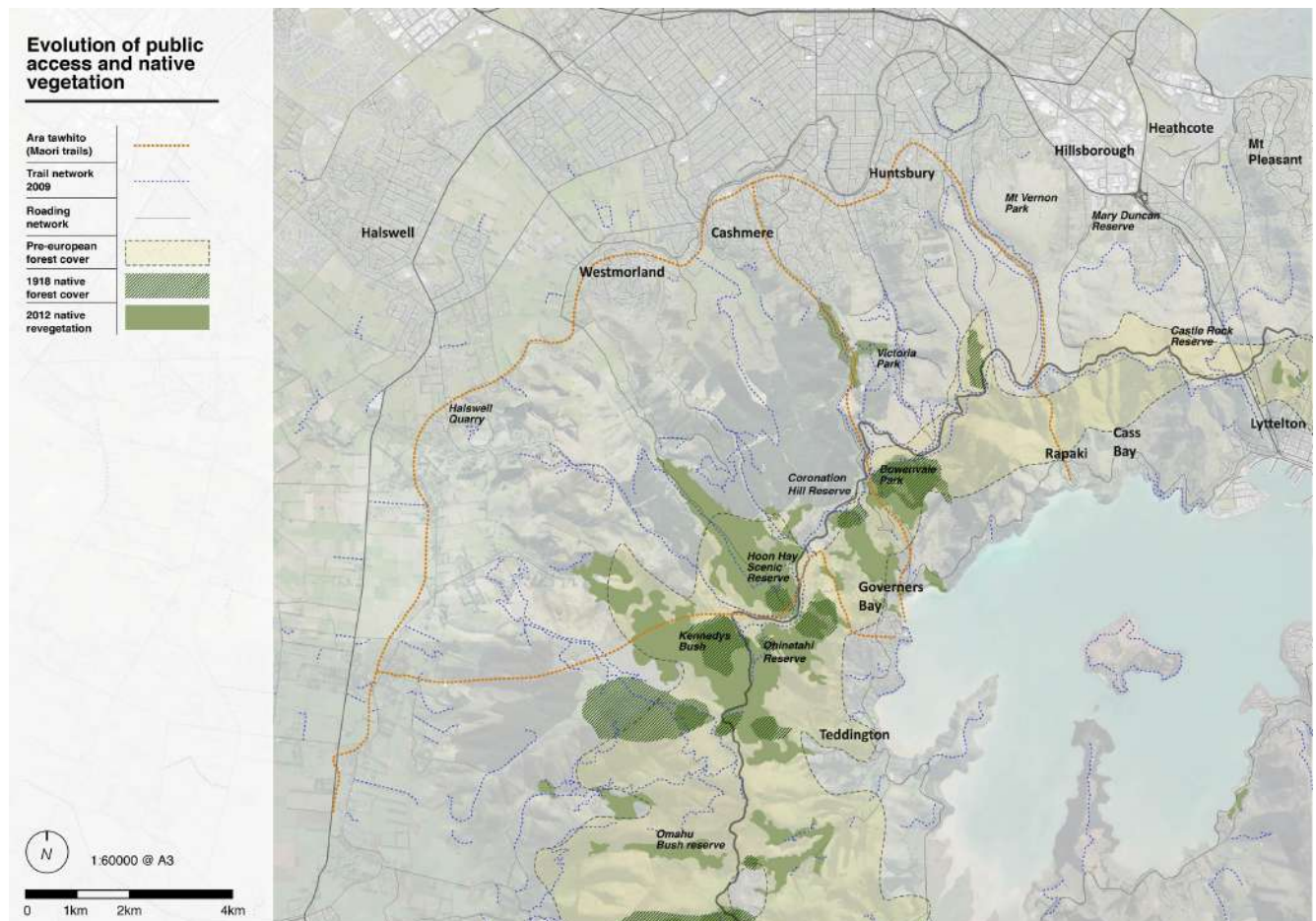


Figure 20 // Evolution of public access and native vegetation in the Port Hills

More recently, groups such as the Rod Donald Trust and Banks Peninsula Conservation Trust are working with the Summit Road Society to extend, update and maintain the Port Hills Public Access and Natural Restoration networks (including open tussock lands) (The Banks Peninsula Conservation Trust, 2018; The Rod Donald Trust, 2016). This maintained and expanded public access network has continued to be a driver for Wildfire issues, with seven significant wildfires started along the upper reaches of the Port Hills over the last 20 years (FENZ, 2017c; Kirk-Anderson 2016; G. Pearce, 2017).

1970 – January 2017 - Continued peri-urbanisation, forestry and intermixed lifestyle blocks

In contrast to the indigenous revegetation priorities of the Scenic Preservation movement, exotic forestry has been planted in bulk upon the Port Hills since around the 1920's, most distinctly within

Victoria Park. In 1935 the majority of this Victoria Park's *Pinus Radiata* forestry block was almost entirely destroyed by a wildfire which was likely caused unintentionally by walker who discarded burning cigarette (The Press, 1935a), exemplifying the particular susceptibility of Pine Forest (Gill, 2005).



Figure 21 // Victoria Park Entrance with Pine Forest around (Godber, 1915-1949)

During the 1960's forestry boom, a big influx of state and private plantings occurred on the Port Hills (Christchurch City Council, 1991), with large expanses of mono-crop *Pinus radiata*, especially on the mid flanks of the northern side of the Port Hills. Following nationwide trends since the late 1980's, these state plantings have steadily become more privatised (Christchurch City Council, 2017c; Purey-Cust, 2001). The extensive private plantations owned by McVicar's were a major factor in creating an extensive network of high-threat fuels and values throughout the Port Hills, as shown with the pre and post 1990 Port Hills forestry extents shown below in Figure 22.

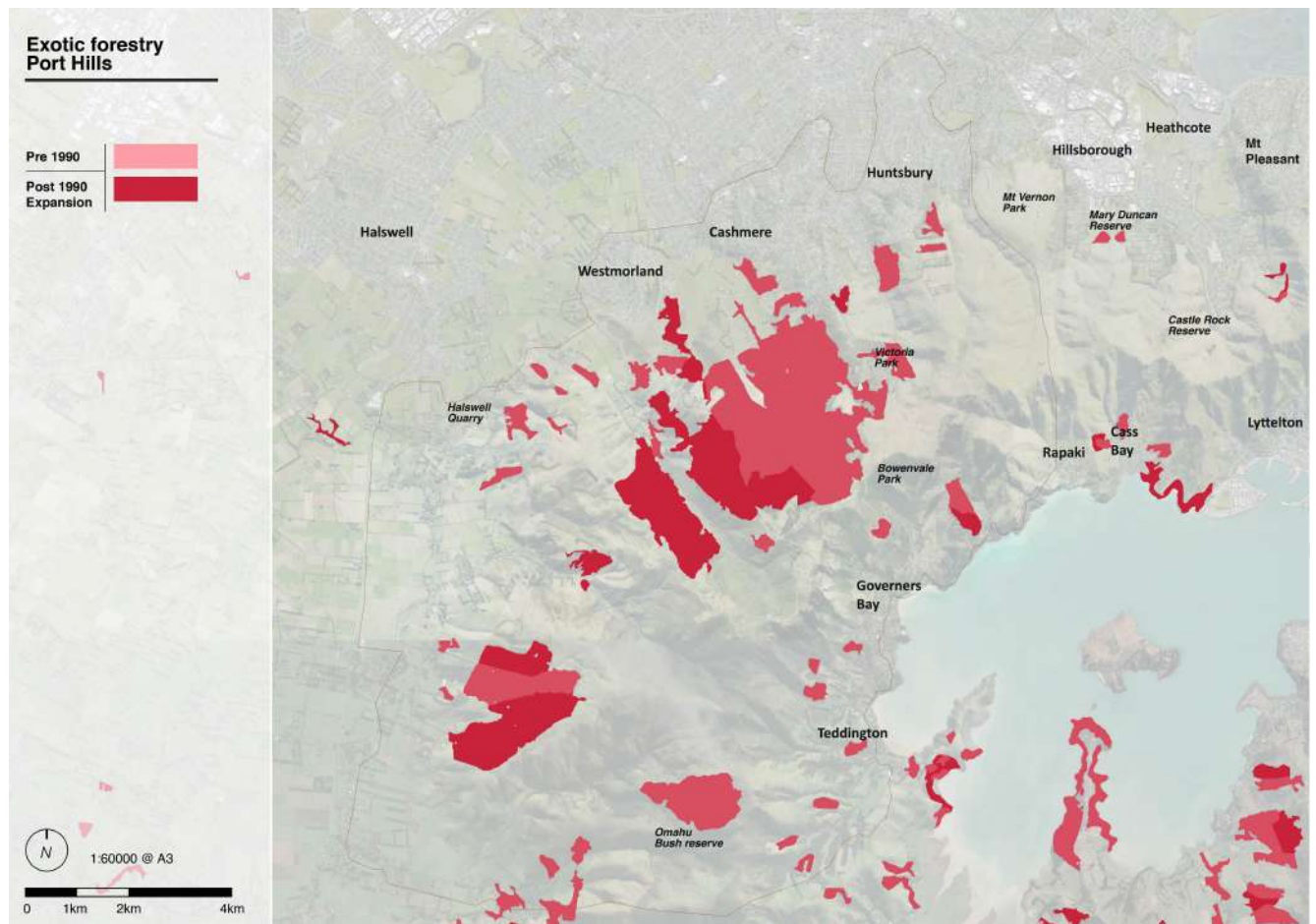


Figure 22 // Exotic forestry expansion pre and post 1990 according to the The New Zealand Land Cover Database (2015)

In the 1970's further subdivision of rural land on the Port Hills occurred, catering to the emergence of 'lifestyle' blocks, where owners live in the country, often with a plot of land, yet work in the city (Robertson, 2016). These properties have a rural component to them, yet have a much higher housing density than rural areas, forming intermixed peri-urban areas. These intermixed Peri-Urban interfaces bring different issues for Wildfire, as they increase the presence of human causes and values within high-hazard areas, while also contributing to this hazard with tendencies of denser and lesser-managed vegetation (Hart & Langer, 2011). The 2017 Port Hill Fires destroyed and damaged several houses on lifestyle properties, and the threat which the fire presented to lifestyle blocks hugely contributed to the widely felt impact of the Fires (Carswell, 2017; McNamara, 2017).

Suburban expansion on the Port Hills is being further encouraged west of Cashmere with Westmorland and Halswell, further extending causal issues for wildfires for example the suspected arson-caused 500ha wildfire on Worsley Spur above Westmorland in 1988 (G. Pearce, 2017; The Press, 1988). This planned capacity for expansion is shown in Figure 23 below.

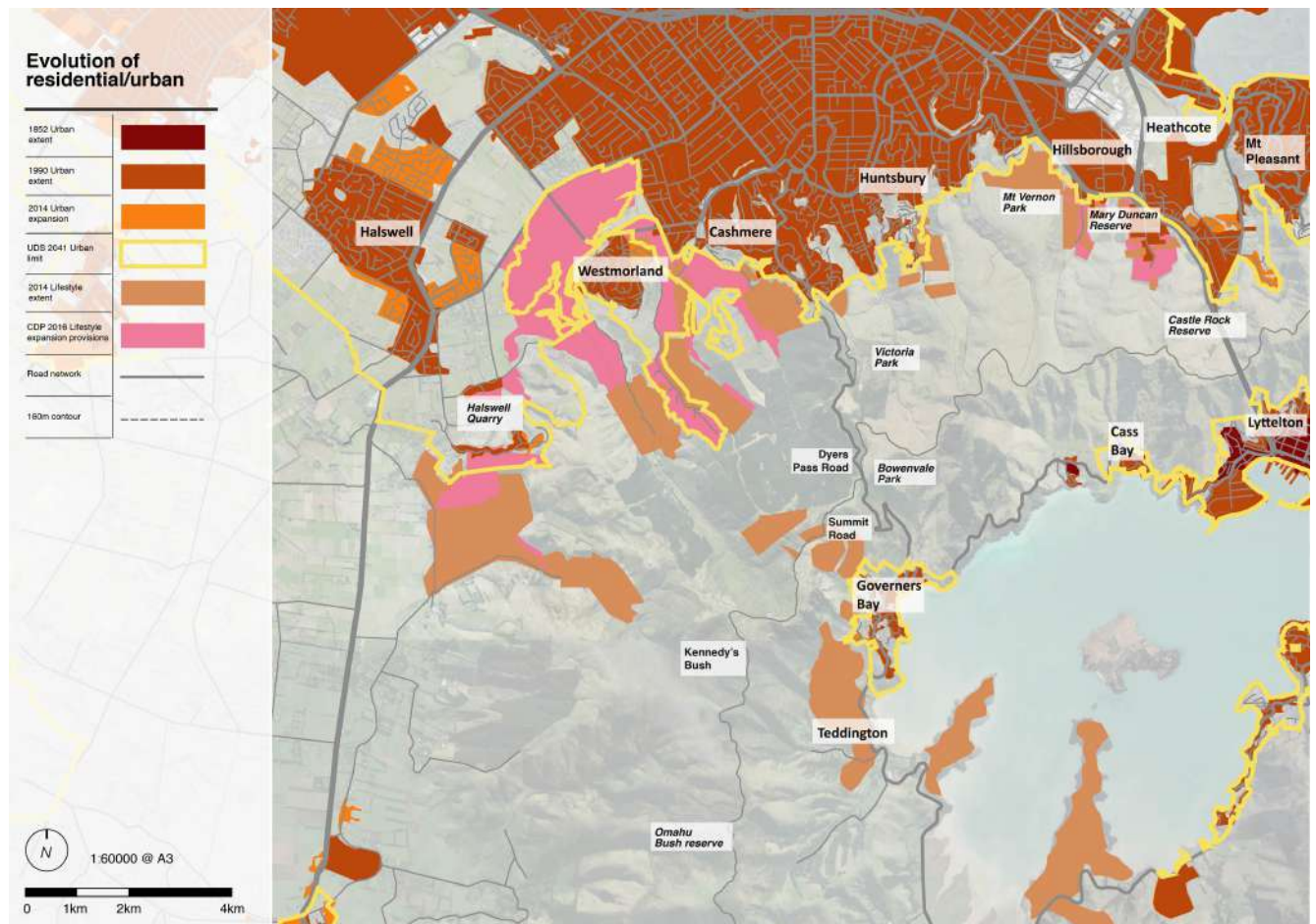


Figure 23 // Evolution of the Port Hills urban extents from red through to yellow, and lifestyle residential extents with dark to light pink.

Statutory planning at the point of the Port Hills Fires

The 2016 operative District Plans for Selwyn and Christchurch both recognise most of the upper, more-visual slopes of the Port Hills as *Outstanding Natural Landscapes* (ONL) which only allows for activities that will have complementary or only minor effects on the landscape values of these areas' (Selwyn District Council, 2016). Along the ridgeline are a series of Outstanding Natural Features (ONF's), which have a similar baseline for activities which affect how the feature looks from outside of the landscape. The less-visual (predominantly lower) regions are recognised as *Significant Landscapes* (SL) which entail a similar yet lesser protection. The Christchurch City Plan 2016 has also enforced that within the Rural and Rural Amenity zoning any subdivision/dwelling above 160m must have a minimum net site area of 100ha and will be considered a non-complying activity, and below 160m will need have a minimum net site area of 40ha and be considered a discretionary activity.

At a regional policy level, the Port Hills sit within the jurisdiction of Canterbury Regional Policy Statement (CRPS, 2017), which applies the requirements the Resource Management Act (RMA, 1991) within the Canterbury region. For the Port Hills, the CRPS 2017 and the non-statutory Greater

Christchurch Urban Development Strategy (UDS, 2016) both look to continue the spatial patterns of a residential base, rural/forestry mid flanks, and natural upper reaches and valleys. This is exemplified in the intended 2041 Urban extents within UDS 2016, as shown with the yellow outline back in Figure 23. The Christchurch City Council and Selwyn District Council regulate and direct Port Hills development towards these regional planning mandates. At this regulatory level, consenting of recent developments such as the 380-home Cashmere Estate reflect the continued peri-urban expansion under statutory planning. Looking forward, the Christchurch City Council's statutory Christchurch District Plan (CDP, 2016) and non-statutory 'South-West Christchurch Area Plan' show provision for further peri-urban expansion with the CDP lifestyle expansion areas shown above in Figure 23, and below in

Figure 24 where an artists impression shows the intent for significant peri-urban development for the Kennedys Bush area (Council, 2009).

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<https://www.ccc.govt.nz/assets/Documents/The-Council/Plans-Strategies-Policies-Bylaws/Plans/area-plans/south-west/SWAP2009FinalDocumentLR-southwest.pdf>

Figure 24 // Artists impression of Kennedys Bush area of Port Hills in the South-West Christchurch area plan (Council, 2009)

Conclusion

The phases of spatial development as detailed throughout this chapter are summarised below in Figure 25 with their impact on wildfire threat. This shows that the spatial configuration and dynamics of expanding forestry and lifestyle blocks, reduced grazing and revegetation, urban expansion, and increased public recreational access have combined to increase wildfire threat on the Port Hills prior to the 2017 Fires (AFAC, 2017; P. J. Jakes et al., 2010).

	Dimensions of Wildfire Threat		
	Risk (Likelihood)	Hazard	Threatened Values
12 million – 8 Millions years ago Volcanic formation			
8 Million Years ago - 1300 CE Mature Forest Canopy cover and erosion			
1300 – 1500 Early Maori and the Intensive Burning Period			
1500 – 1850 Maori Settlement and regenerative with native Scrub and Tussock			
1850 - 1900 European Settlers, native forest harvesting and scrub clearing for pasturelands			
1900 – 1970 Forming the Peri-urban edge and Scenic Preservation			
1970 – January 2017 Continued Peri-urbanisation, with Forestry and intermixed lifestyle blocks			
Statutory planning at the point of the Port Hills Fires			

Legend

No presence of Wildfire Threat Dimension	Low presence of Wildfire Threat Dimension	Medium presence of Wildfire Threat Dimension	High presence of Wildfire Threat Dimension	Very High presence of Wildfire Threat Dimension
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Figure 25 // The development of Port Hills wildfire threat through time, structured within the three wildfire threat dimensions of risk, hazard, and threatened values.

In summary, a belt of settlement encroachment around the base of the Hills has brought urban land uses and values closer to the woody vegetation on the mid slopes, increasing risk and threatened values, and to a lesser extent the hazard dimension of wildfire threat. The mid-slopes of the Hills have developed as an extensive fire hazard zone due to plantation forestry and lightly grazed farmland. An upper band of mixed hazard has emerged, with scrublands and remnant native forest increasing, and overlaid with an expanding public access and recreation network, which bring people to the area and further increases risk and threatened values. These effects are reflected in the historical records of Port Hills wildfires (Figure 26 & Figure 27), which first show the patterns of significant recorded wildfire events in the area, and then by overlaying these on the landuse patterns prior to the Port Hills fires show the implications between the events and the Port Hills landuses.

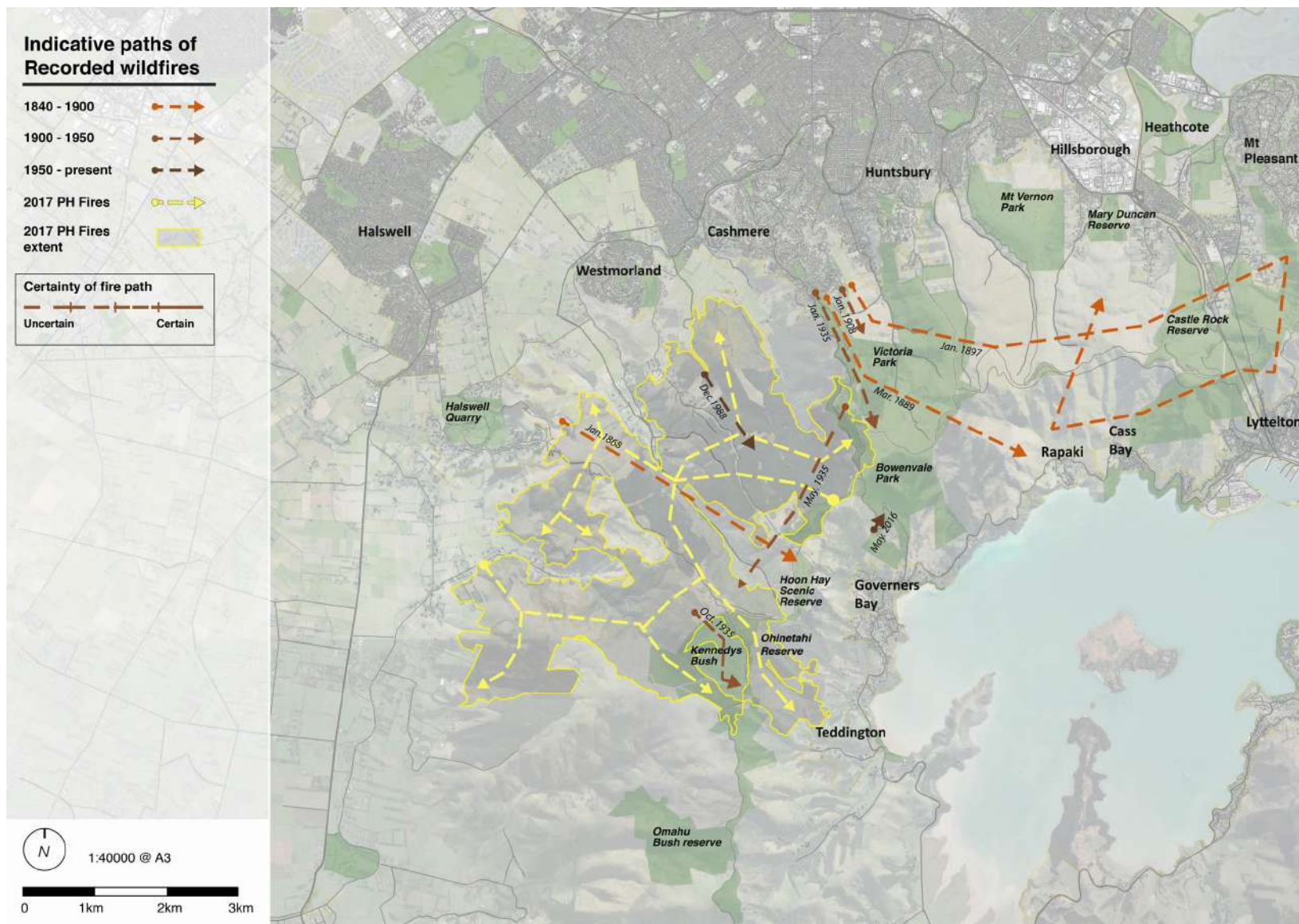


Figure 26 // Location and trajectory of recorded Port Hills wildfires through time

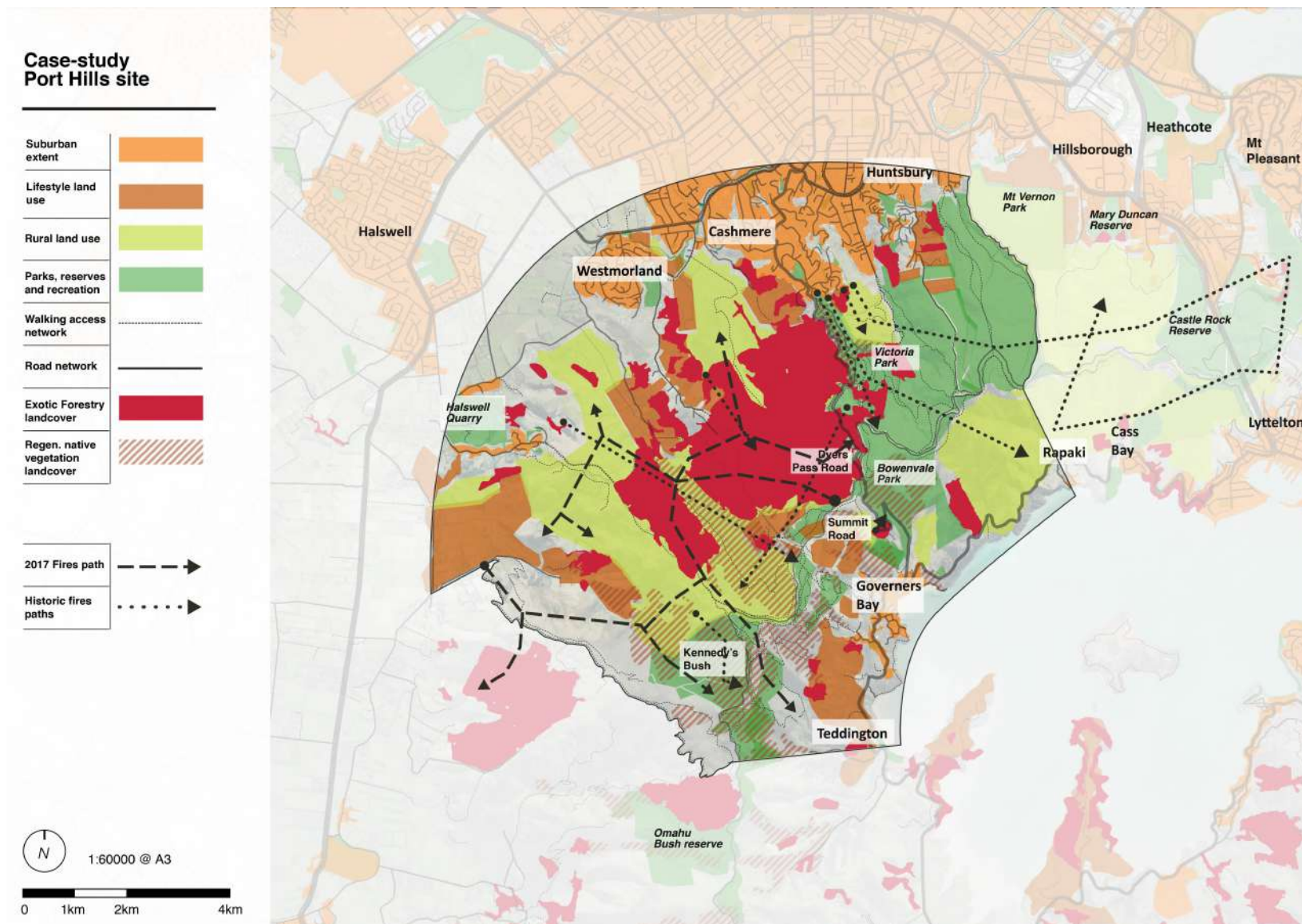


Figure 27 // Case Study site with historic wildfire overlay including the 2017 Port Hills fires



Figure 28 // A burnt stand of Pinus Radiata framing Halswell from Early Valley Road

Chapter 5 The 2017 Port Hills Fires; the event, it's affects, and the recovery

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Figure 29 // Aerial imagery of the Port Hills after the February 2017 fires (Jack, 2017)

The February 2017 Port Hill Fires event

The February 2017 Wildfires consisted of two significant wildfires which both started on the 13th of February 2017. The first started in Early Valley at the base of the Hills, and the second on Marley's Hill close to the ridgeline of the Port Hills. Both fires were likely caused by arson, with the Early Valley Road Fire starting at the boundary between Lifestyle/Suburban Residential and Rural areas, and the Marley's Hill Fire started near a carpark along the Summit Road (Hayward, 2018). They later joined into what has been titled the Port Hills Complex (AFAC, 2017). The fires covered an area of over 1661 hectares, with a perimeter of 61 kilometres, straddling the jurisdiction of both the Selwyn District and Christchurch City Councils (AFAC, 2017; Langer, 2018). The extent and path of the event is shown below in

Figure 29. On the 15th of February a state of emergency was declared, and the fire were not fully extinguished until 66 days later (Christchurch City Council, 2017c).

The east coast of New Zealand was at the time primed for such an event, with several Wildfire Events already occurring throughout the North Island east coast during January and early February (Langer, 2018). Hot and dry winds were coupled with very little rainfall to dry-out the extensive mosaic of vegetative fuels which stretch across the Port Hills, creating a high seasonal risk of Wildfire alongside the already high Port Hills Wildfire Threat (AFAC, 2017; Langer, 2018). The situational Port Hills Wildfire Threat and seasonal Wildfire Risk are shown below in Figure 31 to Figure 34.

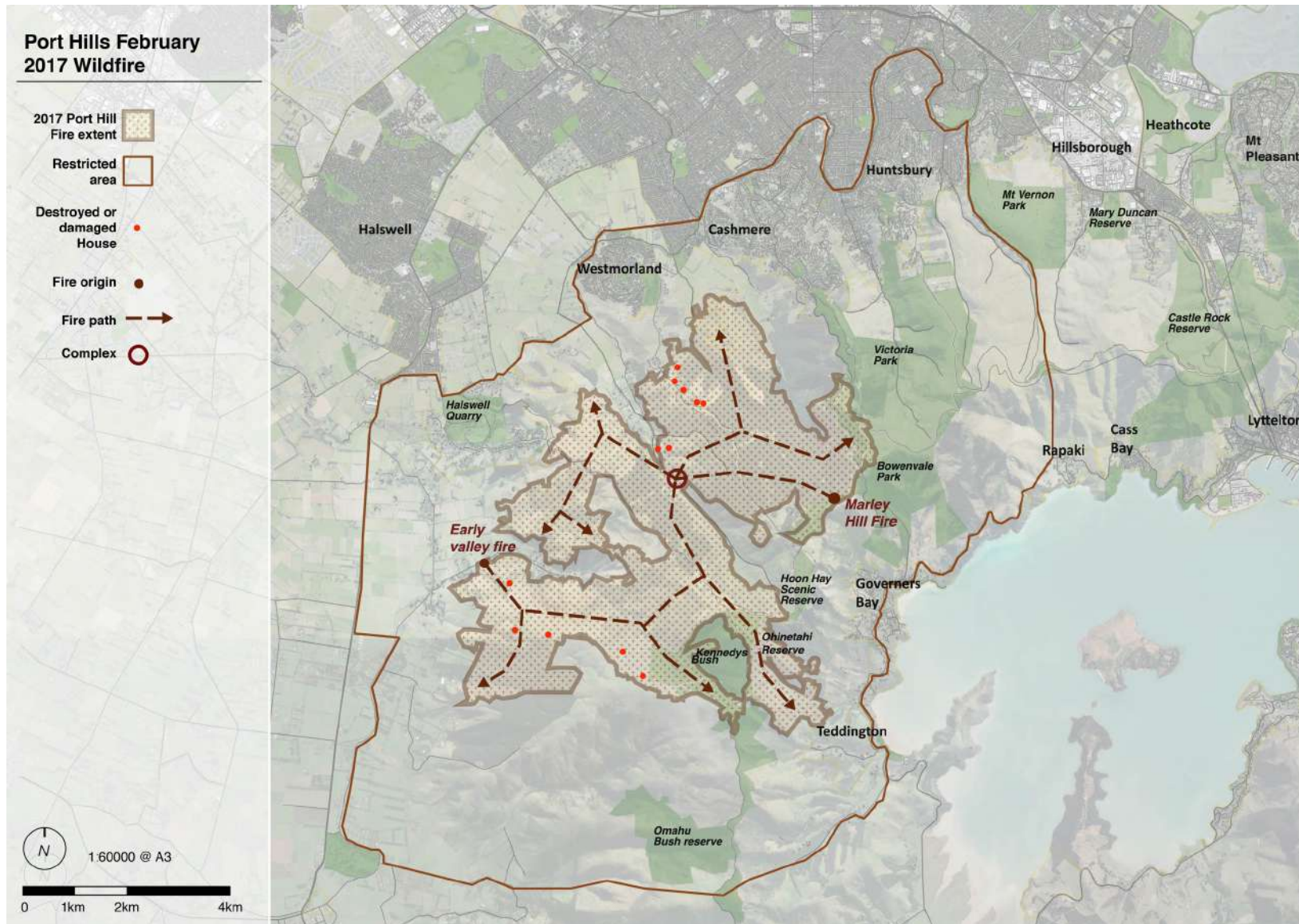


Figure 30 // Extent and indicative path of the 2017 Port Hill fires, interpreted from (AFAC, 2017)

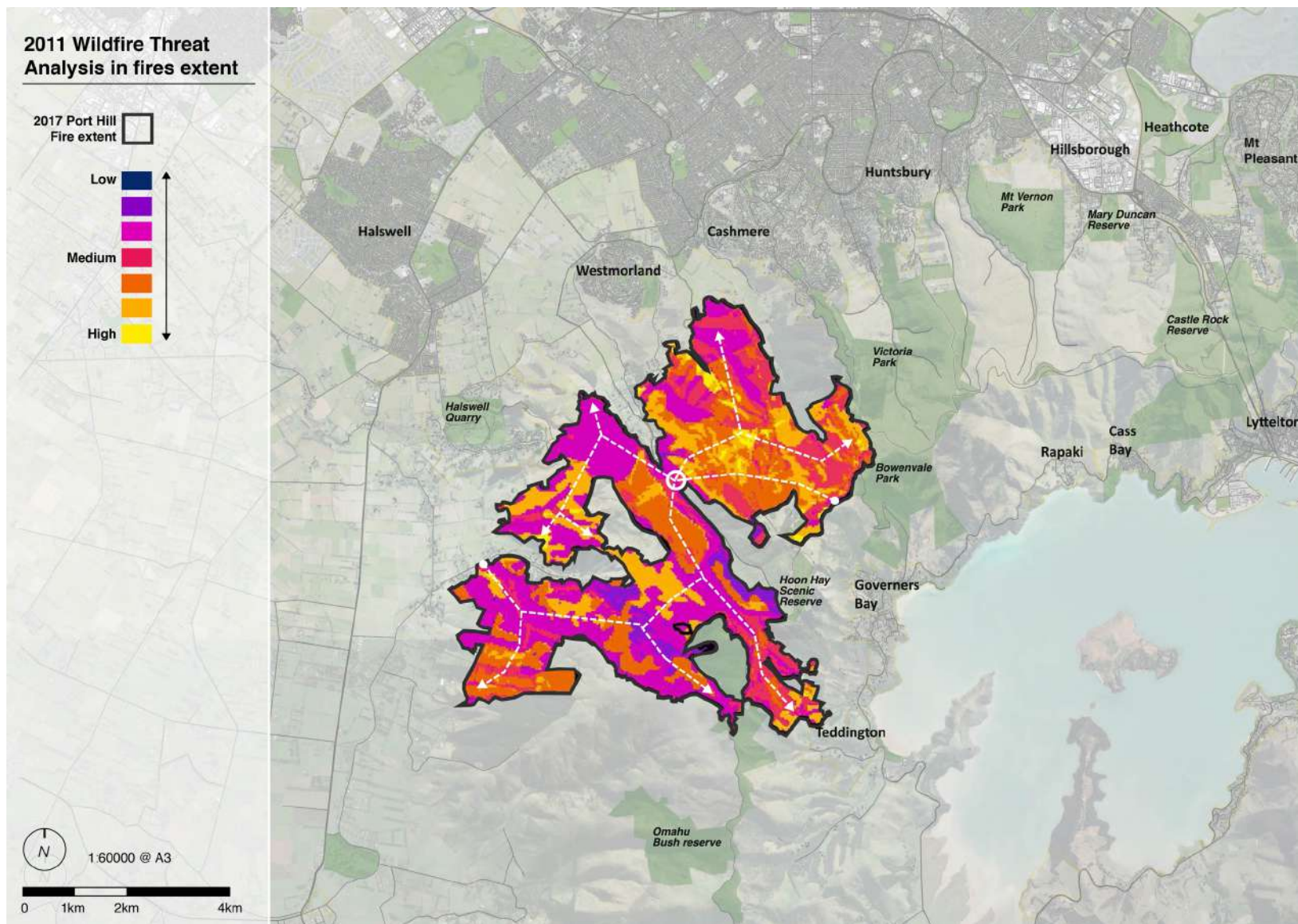


Figure 31 // 2011 mapped Wildfire Threat before the event, shown the extent of the 2017 Port Hills Fires, interpreted from (AFAC, 2017)

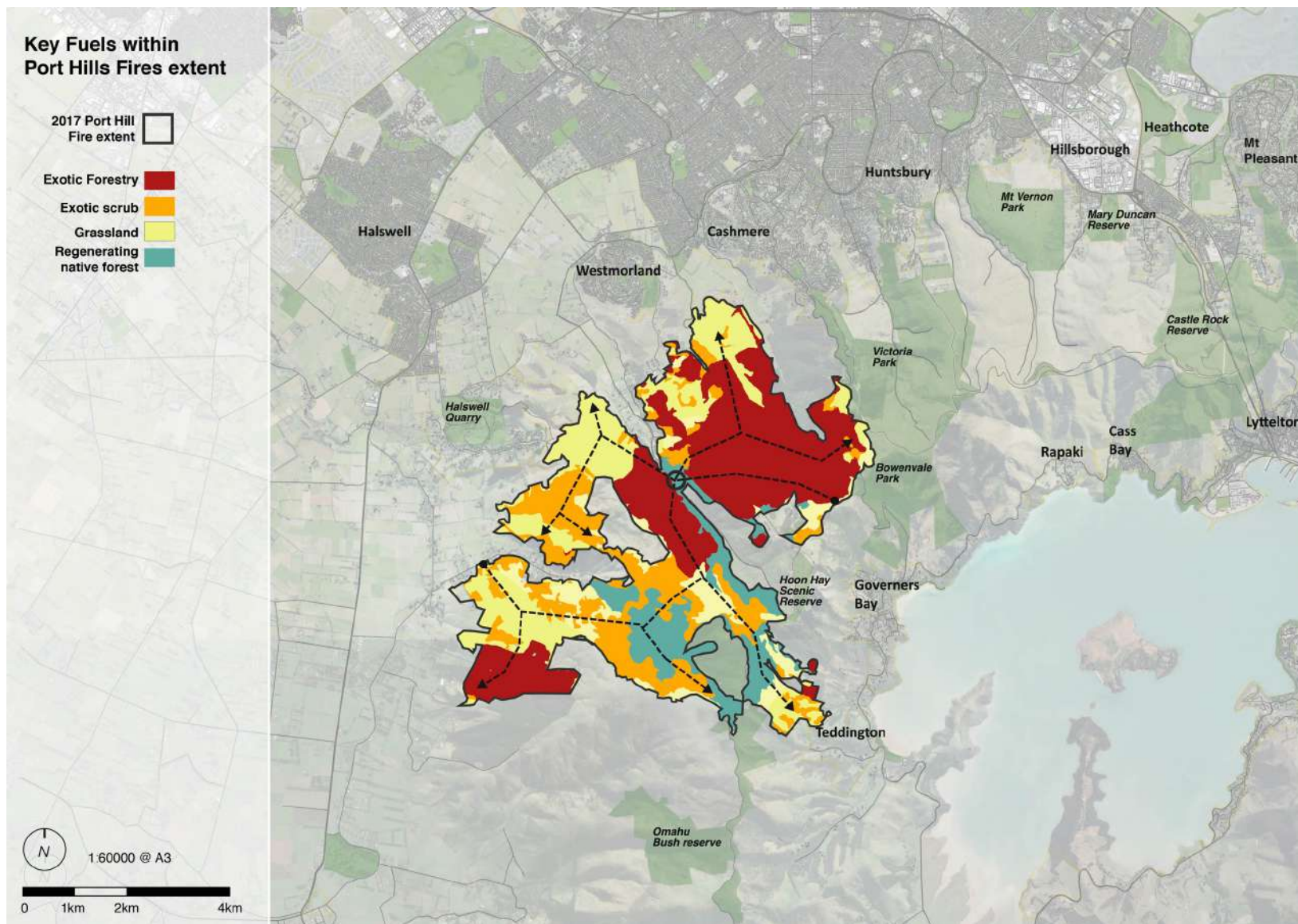


Figure 32 // Key fuel types that were burnt during the 2017 Port Hills Fires

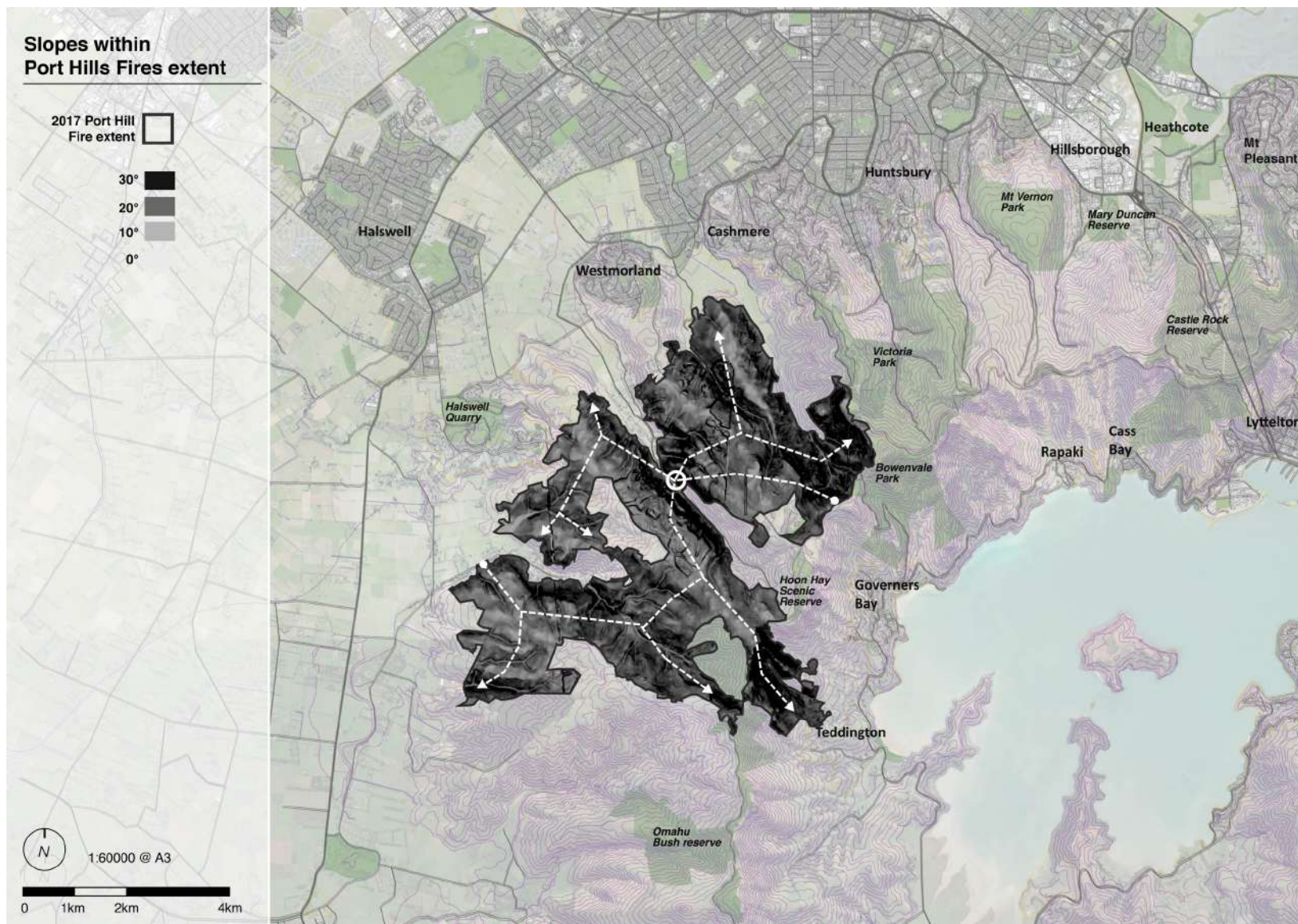


Figure 33 // Slopes within the extent of the 2017 Port Hills Fires

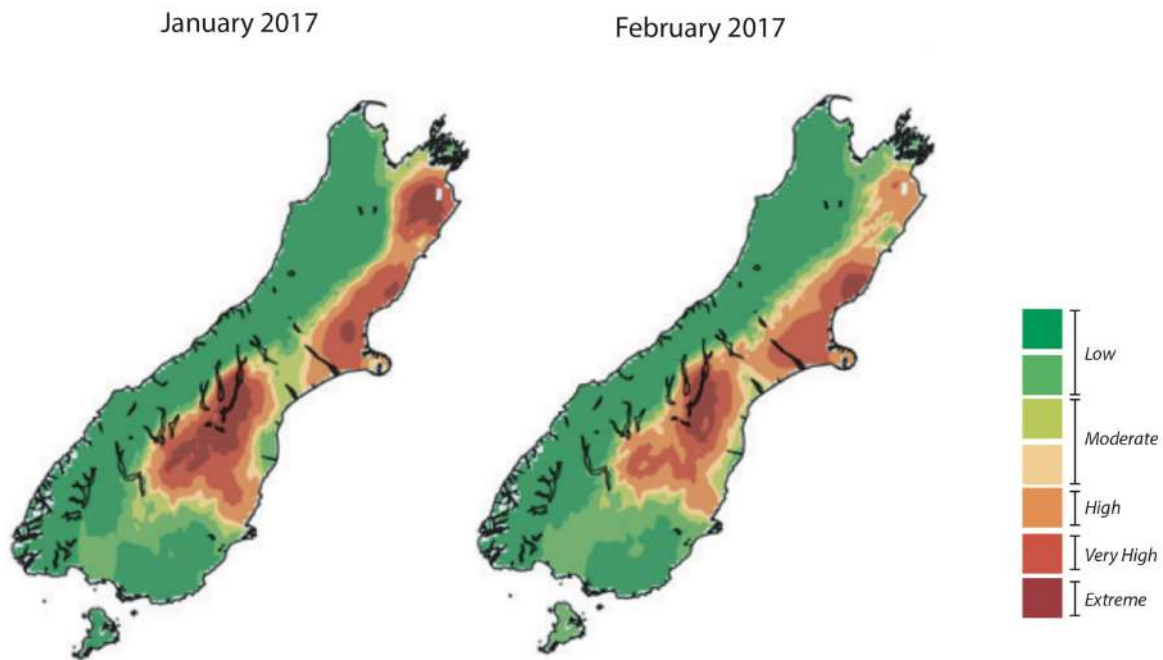


Figure 34 // Wildfire Risk for January and February 2017, interpreted from (SCION, 2017)

The dry fuels of the complex mosaic of woody vegetation led to a high hazard in the Port Hills, with the fires fuelled by the large tracts of exotic forestry and grassland, along with patches of exotic regenerating broadleaf scrubland (AFAC, 2017; Christchurch City Council, 2017c). Vegetation burnt in the February Fires are shown above in Figure 32. The patches of Indigenous mature forest proximate to the fires were largely unburnt, with the most hazard-causing built element being the Adventure Park chairlift, which is thought to have brought the fire down the Hills towards a denser concentration of fuels and values (AFAC, 2017; Hayward, 2018). The steep ridges and gullies (shown above in Figure 33), along with changing winds contributed immensely to the speed and intensity of the fire (AFAC, 2017).

The 2017 Port Hills Fires had particularly significant Peri-Urban effects (Langer, 2018).

Internationally, they were of a moderate scale and impact, however they were some of the largest and most significant wildfires in New Zealand's history (Langer, 2018; Strand, 2017). Many values were affected in the Port Hills, including the very tragic death of helicopter Pilot David Steven Askin who died fighting the fire, and the destruction and damage of several homes (Christchurch City Council, 2017b). A further 450 homes were threatened by the fires, and approximately 1400 residents were evacuated from both lifestyle and suburban areas (Langer, 2018).

Properties assets on farmland and lifestyle block (such as fences) were extensively damaged and destroyed, while civil infrastructure such as transmission lines were also damaged and threatened. Roothing, public access and recreation networks were widely affected, including the recently opened Adventure Park, while regenerating conservation areas such as Ohinetahi Bush were extensively burnt (Christchurch City Council, 2017b; Langer, 2018; Northcott, 2017).

Media articles have also depicted the deep affects on the local and broader Christchurch community, with the charred tracts of scrub, grass, and forest standing as a reminder upon Christchurch City's 'scenic backdrop' (Leask, 2017; Muerk, 2017; Strand, 2017). This impact upon the community is a truly distinguishing feature of the 2017 Port Hills Fires, in that they dramatically laid bare the Wildfire implications of the Port Hills as a Peri-urban extension and amenity for Christchurch City (Carswell, 2017).

In the weeks leading up to the 2017 Fires, there was an awareness of the situational and historical wildfire threat, as well as the seasonal Wildfire Risk, which had been publicised and enforced with a fire ban throughout the area (AFAC, 2017; Langer, 2018). This likely contributed to the widely felt public concerns around the effectiveness of the emergency response and communication throughout the event (Christchurch City Council, 2017c). These operational issues have been independently reviewed, and have found the concerns to be founded, and gave recommendations for improving Wildfire Management throughout the recovery from the fires.



Figure 35 // Day three of the Port Hills Fires above Westmorland (Vallance, 2017)

Recovery Plans

The 'Port Hills Fires Recovery Plan' (PHFRP) was released in June 2017 and set the institutional framework for the recovery. This document involves a wide range of governing bodies including Christchurch City Council (CCC), Selwyn District Council (SDC) and Environment Canterbury (ECAN). It gives a strategic framework for the 'coordinated recovery from the Fires, responding to the short, medium and long-term social, built, economic and natural issues' (Christchurch City Council, 2017c).

The independent Port Hills Operational Review (PHOR) was produced for Fire Emergency New Zealand (FENZ) in November of 2017. The document focuses on detailing and reviewing the Operational Management of Port Hills Wildfire event, however it also evaluates and actions more forward-thinking approaches to managing wildfire threat. These actions are further detailed by FENZ in their 'Operational Action Plan' (OAP), which followed the review.

Other less-formal groups have also worked to plan-out the recovery, such as the Ecological Recovery group, who within a month of the event produced a indigenous revegetation strategy. This lays out required actions for indigenous revegetation of the Port Hills (Muerk, 2017). Another example of less-formal groups is the farm-owners in Lansdowne Valley, who within a week of the fires had planned-out and begun to implement aerial reseeding of scoured earth with pasture grasses such as Italian rye (Christchurch City Council, 2017a; S. Taylor, 2017).

These approaches all work within the recovery phase, but have varied mandates to reinstate or improve Wildfire Issues in the Port Hills. The following section therefore examines the overall recognition of Wildfire Management within recovery plans.

Wildfire Management and Threat within the Recovery

Wildfire threat description was undertaken for the Port Hills in 2011, and was further refined as part of the PHOR after being deemed too low (AFAC, 2017). This is shown above in Figure 31, and reflects international standards of Wildfire threat description. Further development of projected wildfire risk as shown in Figure 34, is laid out by the PHFRP, and also features in the OAP (FENZ, 2017c).

The OAP reflects international approaches to social development with a concentration on at-risk collaborative community input and uptake (FENZ, 2017c), while the PHFRP (as the central strategic document) focuses predominantly on 'one-way education', 'community recovery support', and improving 'warnings and emergency communication' (Christchurch City Council, 2017c). Furthermore, while the Recovery Plan document was informed by community consultation

meetings, this was focused on community expectations of governance, rather than specific development of Wildfire Threat and Management awareness and capacity. PHOR and OAP however recognise and action the research and development of co-constructed education, indicating uptake and awareness of International best-practice (AFAC, 2017; FENZ, 2017c).

Land-management strategies within the PHFRP and OAP follow International best-practice by focusing on improving readiness, such as preparing emergency responses for future wildfire events and working towards improved fuel management (Christchurch City Council, 2017c; FENZ, 2017c). The less-formal groups also work largely on land-management and more specifically fuel management, for example the farmer-led re-seeding of rye grass has effectively controlled gorse (S. Taylor, 2017), which has reduced fuel loading with the caveat of the new pasture needing grazing to avoid seasonal wildfire threat. The Ecological Recovery group with their indigenous revegetation strategy looks to effectively replace the previous extents of exotic vegetation (fuels) with less-flammable native species, and to some degree works at a larger spatial scale to arrange revegetation into greenbelt fire breaks (Curran, Perry, Wyse, & Alam, 2018; Muerk, 2017).

In the PHFRP, spatial planning is identified as an opportunity but this is given a 'where practical' proviso, and the review of spatial planning opportunities will only focus on the urban component. Furthermore, the review will only consider land use from mid-2019 onwards, when approximately two thirds of the recovery capital will have already been invested (Christchurch City Council, 2017c, 2018a). The PHOR and OAP do not make mention of spatial planning (AFAC, 2017; FENZ, 2017c).

Overall, there is a as distinct lack of spatial planning and its potential as a wildfire management strategy. Instead, the PHFRP as the key spatial recovery document approaches the recovery with a largely restorative approach. This involves reinstating the pre-fire land uses and built environment, with the specific preservation and rebuilding of residential, commercial and utility structures and assets within the Port Hills (Christchurch City Council, 2017c). Native revegetation efforts have thus far also concentrated on reinstating pre-fire indigenously vegetated areas (Burry, 2018).

In summary, a year on with the recovery well underway, the mosaic of flammable vegetation cover interwoven with high value assets and a dense network of public access is being largely restored and reinstated.

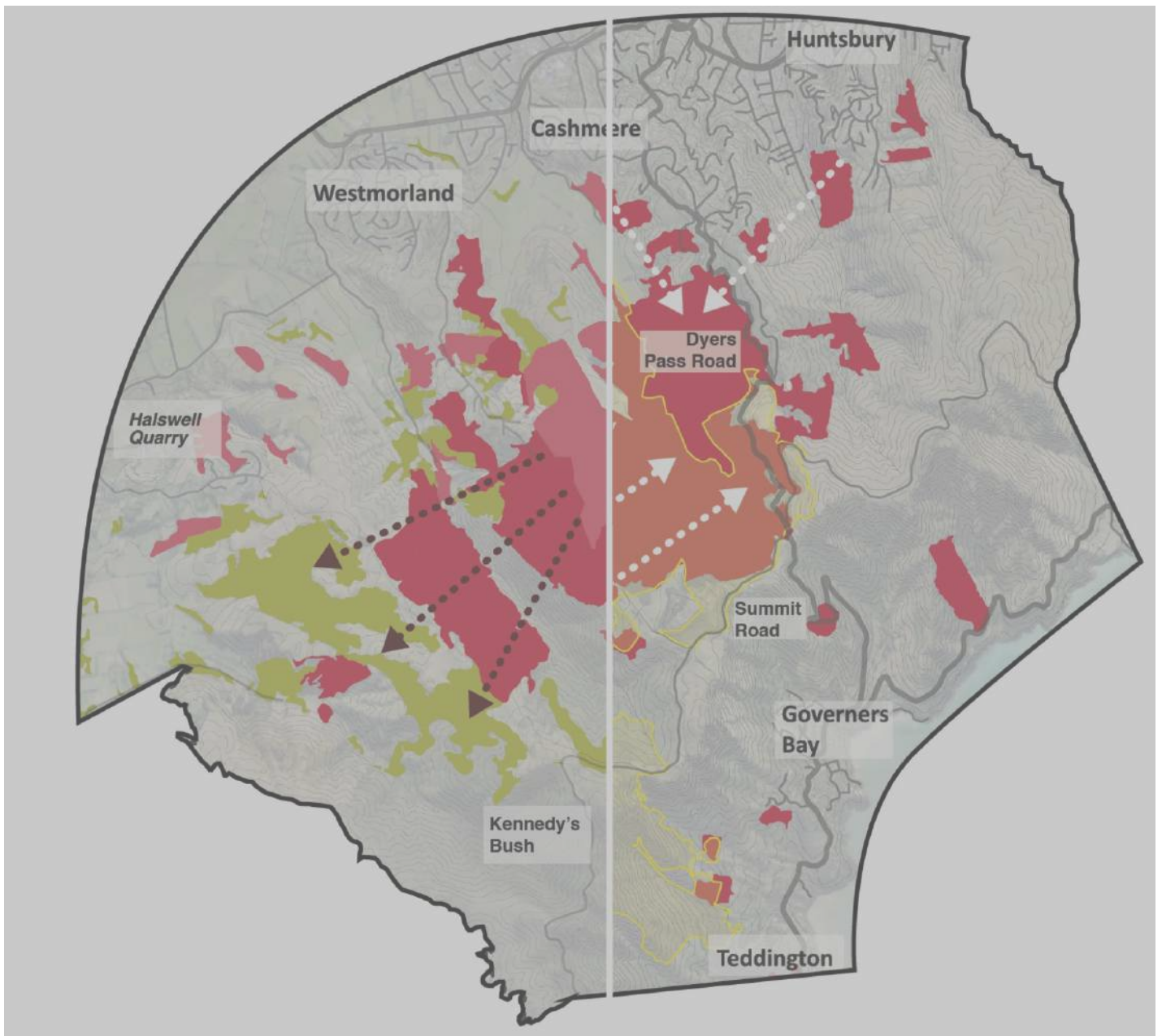


Figure 36 // Alternative trajectories for Exotic Forestry on the Port Hills

Chapter 6 Port Hills Alternative Futures

Theoretical framework for applying design-led alternative futures to the case study

Design-led alternative futures are a way of effectively exploring and evaluating spatial change (Swaffield, Primdahl, & Hoversten, 2013). In this thesis, the alternative future approach is used to normatively evaluate the likely spatial trajectories of the case study (Corry & Nassauer, 2004), comparing them against a future in which wildfire threat is managed through spatial planning. Three alternative futures are explored, firstly the trajectory of Port Hills statutory planning and secondly the trajectory of the Scenic Preservation movement, as the prominent ground-up spatial planning imperative in the Port Hills area. The third future of wildfire management involves collating relevant international examples of spatial planning for wildfire management, integrating them into case study site.

Aligning trajectories with the normative future of Wildfire Management provides insight into the implications of current spatial planning with regards to wildfire threat, and by highlighting these implications can effectively assist decision making about the future of the area (Corry & Nassauer, 2004; Deming & Swaffield, 2011). For example, by drawing attention to questions such as, *should the patterns of large mid-flank Pinus Radiata forestry plots be retained alongside the continued expansion of neighbouring suburban and lifestyle residential land-use, when these patterns are likely to be deeply affecting Wildfire Threat?*

The three futures have been selected with clear points-of-difference because their purpose is to reveal broader implications such as the example given above, rather than finer scale consequences (Hoversten, 2014). As a broader scale inquiry, design-led alternative futures specifically allow for uncertainty, and require designing rather than formulaic modelling of proven information (Corry & Nassauer, 2004; Deming & Swaffield, 2011). This approach suits the limited capacity of a Master's thesis, and serves the purpose of the research to evaluate the potential of Spatial Strategies to manage wildfire threat in the Port Hills, rather than developing site-specific Spatial Planning strategies for Wildfire Management.

While the alternative futures are not a formulaic modelling process, the design decisions which form each alternative futures are explicitly substantiated to create a more relevant evaluation (Deming & Swaffield, 2011; Hoversten, 2014), and are discussed below for each alternative future, along with their specific relevance to the case study landscape.

Assumptions

Landscape is considered in this thesis to be a series of overlapping and interrelated land-covers and land-uses, which change over time due to various pressures (Rastandeh, 2015). Therefore, the case-study landscape has been classified into key land-covers and land-uses. A review of Port Hills landscape evaluations, landuse mapping and several site-visits revealed eight key landscape categories (Boffa Miskell, 2015; D. Hogan, 2014; LUCAS NZ, 2017). These are detailed below, and are illustrated within the case study site in Figure 37 on the following page.

Suburban residential – A fluctuating belt of suburban residential land-use extends around the lower flanks of the Port Hills.

Lifestyle residential – A mosaic of lifestyle residential land-use extends from the lower flanks of the Port Hills up to the upper-mid flanks.

Roading and utility networks – Utilities (e.g. powerlines and roads) extend across the Port Hills.

Recreation and public access networks – Recreation and public access routes and areas extend throughout the Port Hills.

Water networks – Various natural and human water systems exist on, and near the Port Hills.

Pastoral farming – Large bodies of rural pastoral land-use characterise the mid flanks of the Port Hills and in places extend onto the lower and upper flanks, within farm and lifestyle properties.

Exotic forestry – A band of exotic forestry extends around the mid-flanks of the Port Hills.

Indigenous revegetation – Pockets of indigenous revegetation extend throughout the Port Hills, especially on the upper flanks and in the valleys.

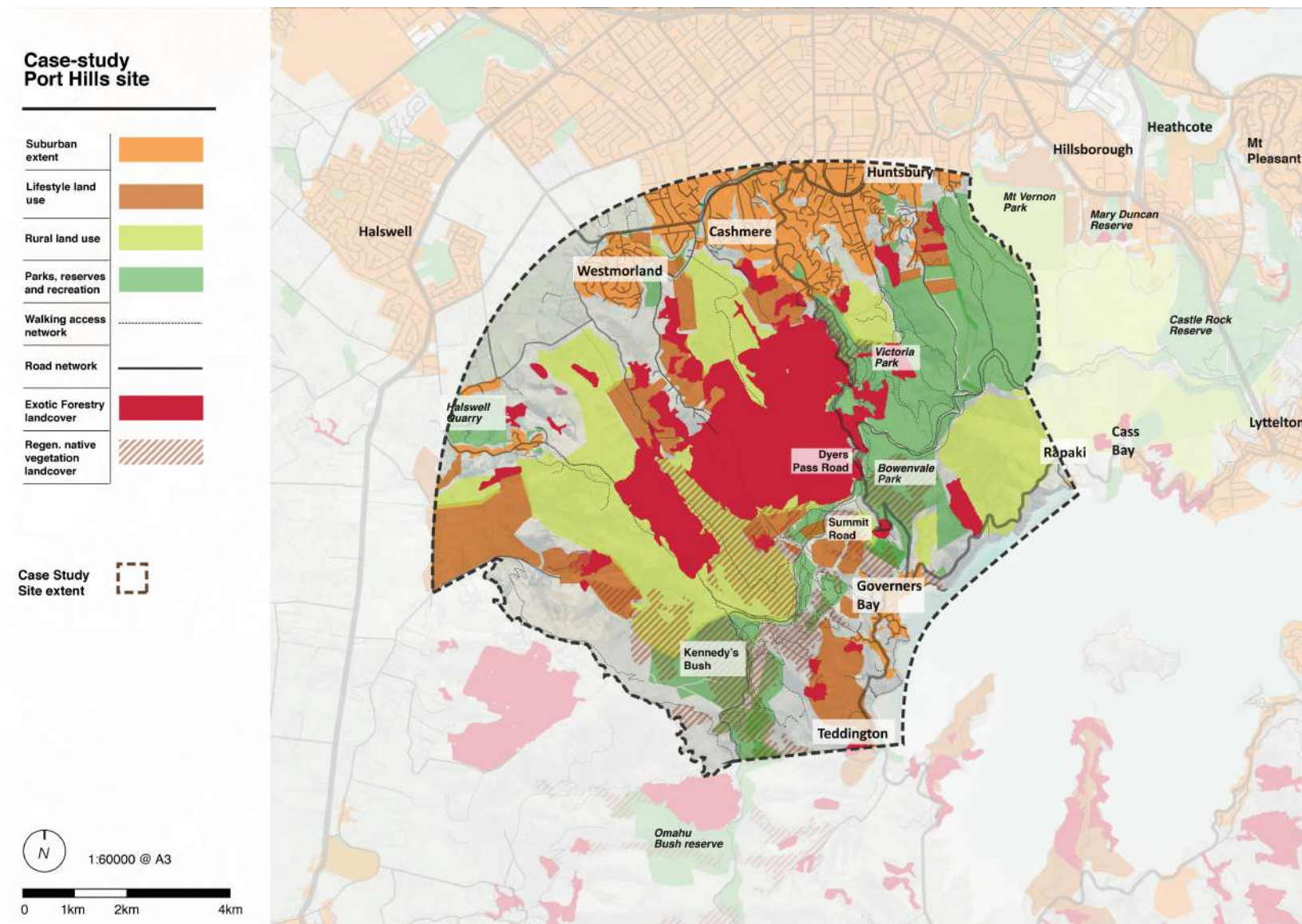


Figure 37 // Case-study site with landscape categories prior to the 2017 Port Hills Fires, as listed in the key.

The following sections give the basis for each Alternative Futures, first describing and illustrating the trajectory of change for each landscape category given above, before presenting the consolidated alternative future map. The sections start with a summary of the lens being adopted for each alternative future.

Alternative Future A - Statutory Planning Port Hills

The formal 2017 Port Hills Fires Recovery plan as detailed in Chapter 5, adopts a largely restorative approach to the affected area, especially regarding build structures and economic assets. While the 2019 scheduled exploration of 'planning opportunities to reduce wildfire hazard in high risk areas' (Christchurch City Council, 2017c) may affect change in statutory planning for the area, it is assumed that these reinstatement mandates will lead to the continuation of pre-fire statutory planning trajectories.

Suburban and Lifestyle residential trajectory

The 'Canterbury Regional Policy Statement 2017' and the 'Greater Christchurch Urban Development Strategy 2016' both specify several areas of residential expansion upwards onto the Port Hills, especially up the south-west spurs with hillside Halswell and Westmorland (Environment Canterbury, 2016, 2017). These provisions are reflected within the Christchurch district plan, in which residential zoning extends to the 2028 urban boundary and allows for a mixture of lifestyle and denser suburban residential development (Christchurch City Council, 2016). These trajectories are reflected in the non-statutory South West Area Plan as depicted in

Figure 38 below (Council, 2009). Overall, leap frog suburban development is likely to continue up the lower flanks and especially up the south-west spurs, while lifestyle residential will expand across the lower and mid flanks. This trajectory is exemplified by the consented Cashmere Estate development shown in

Figure 38 below, which involves 380 new houses on rural land below Cashmere.

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<https://resources.stuff.co.nz/content/dam/images/1/i/4/c/p/q/image.related.StuffLandscapeSixteenByNine.1420x800.1i405g.png/1490593662053.jpg>

Figure 38 // Cashmere Estate Development, which is currently underway (Cashmere Estate Ltd, 2017)

Suburban residential

Leapfrog expansion on lower flanks, especially on spurs and south of Dyers Pass Road

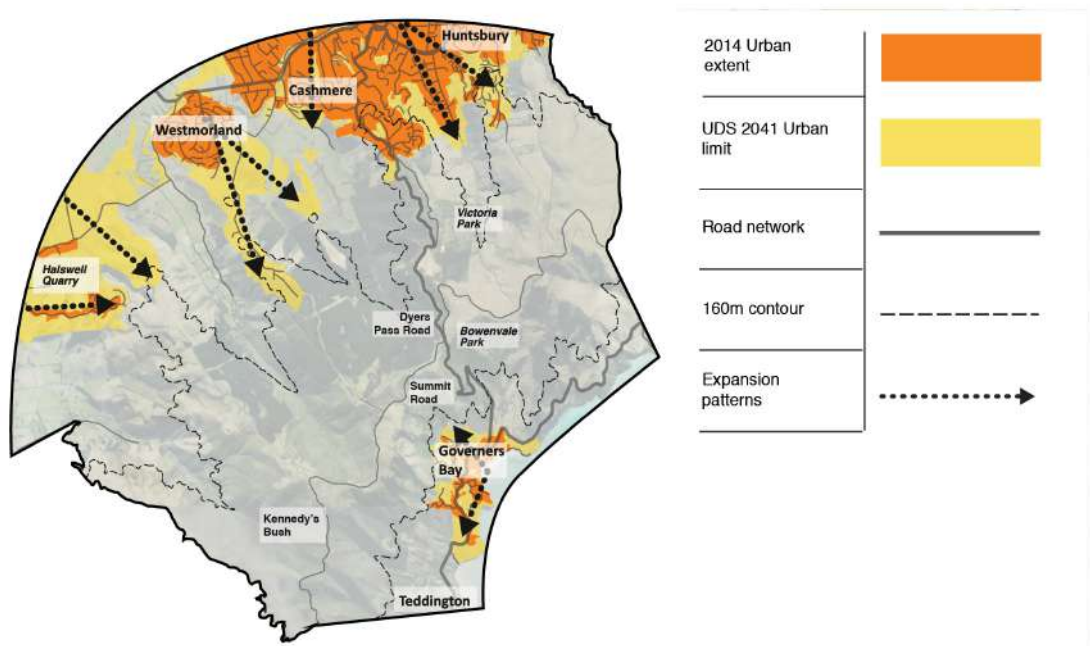


Figure 39 // Suburban residential trajectory for Alternative Future A

Lifestyle residential

Leapfrog expansion on lower flanks, especially on spurs and south of Dyers Pass Road

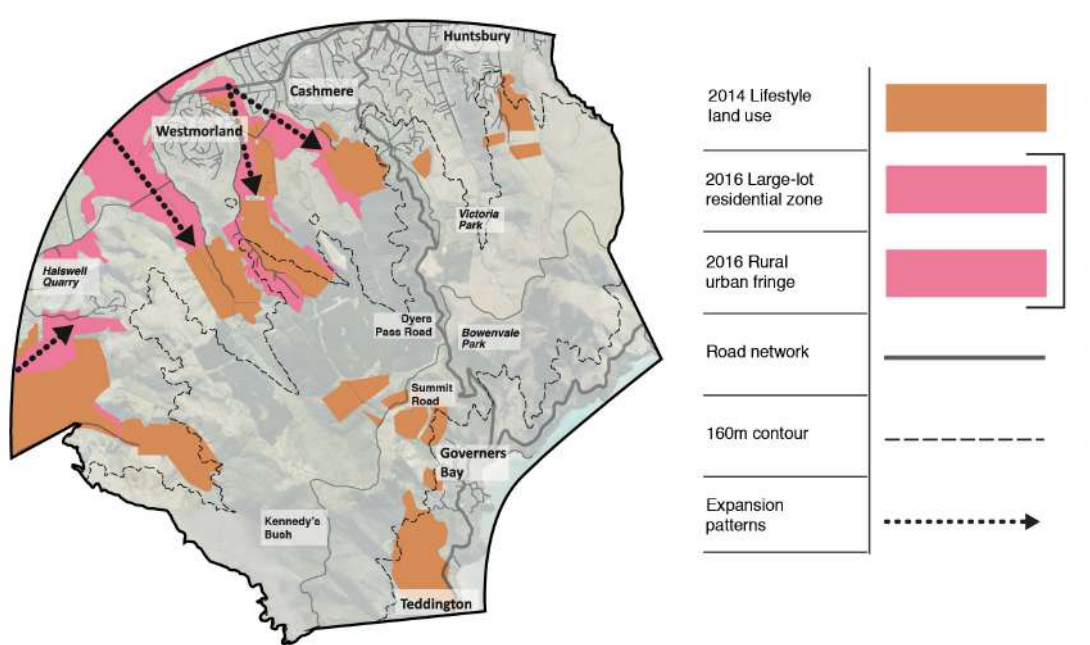


Figure 40 // Lifestyle residential trajectory for Alternative Future A

Roading and utility network trajectory

Utility 'lifelines' including roading, water supplies, power supplies, and transport links were widely affected by the fires, which reinforced protective mandates around them (Christchurch City Council,

2017c). Alongside protection of existing networks, it's necessary that these networks expand for the connectivity and functionality of residential development (Environment Canterbury, 2016). In roading terms, it's therefore expected that a system of upgraded arterial roads will link this Port Hills development to Christchurch, while a dense pattern of cul-de-sac and local access roads will extend within development areas. This will be reflected within other networks such as power and water supplies. The Christchurch District Plan shows an increase in vehicular connectivity across the Port Hills, with roads such as Worsleys Road (which plays an arterial role for upper Westmorland) extending along what is currently a non-vehicular road to connect with the Summit Road. The Summit Road will be maintained and protected for its amenity values, though likely managed for night-time access (Christchurch City Council, 2018b). In summary, a trajectory being flowed where the lateral running Summit Road will be maintained as a fundamentally scenic spine, while the adjacent networks will expand to cater for development on the Port Hills flanks.

Roading and utility network

Protect scenic access, expand to cater for residential demand, and control Summit Road

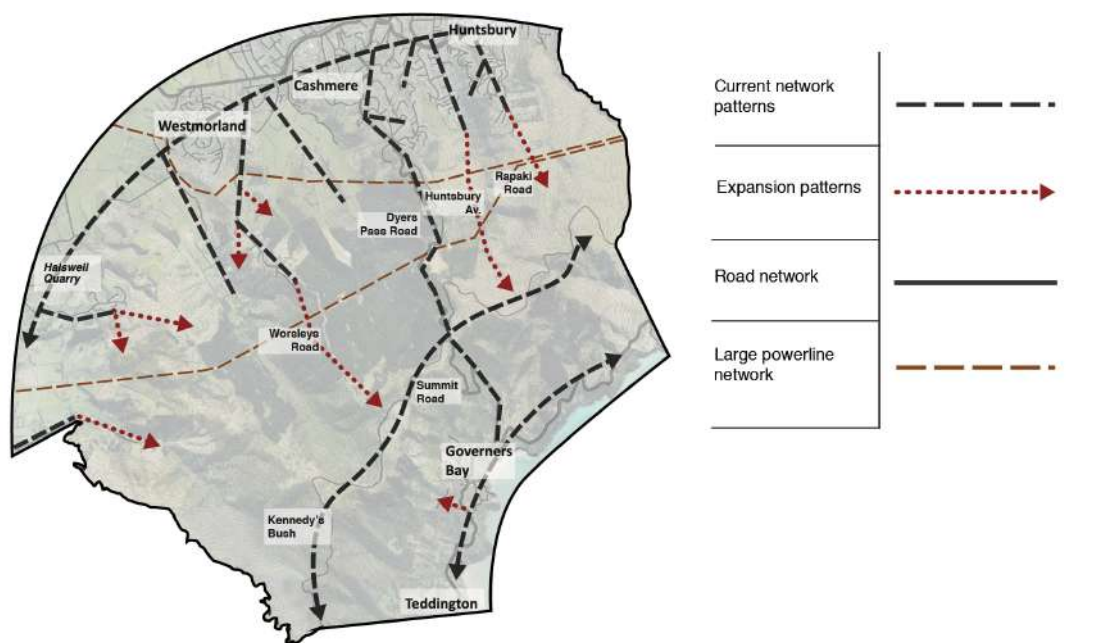


Figure 41 // Roothing and utility network trajectory for Alternative Future A

Recreation and public access network trajectory

The Port Hills public access and recreational networks is extensive, and considered highly significant for Christchurch city (Rob Greenaway & Associates, 2004). Within the 'Open Space' objectives under the Christchurch District Plan, the development of recreational activities is limited for the protection of Open Space landscape character, focusing on a functional, visually unobtrusive role for recreation (Christchurch City Council, 2016). However, significant commercial development such as the

Adventure Park have shown that there is space for economically-driven expansion that furthers the diversity and connectivity of recreational activities (Christchurch Adventure park, 2016). Therefore overall, that current trajectory involves maintaining and diversifying public access and recreational networks, and increasing the ‘city-to-summit’ connectivity.

Public access and recreation networks

Maintain and diversify

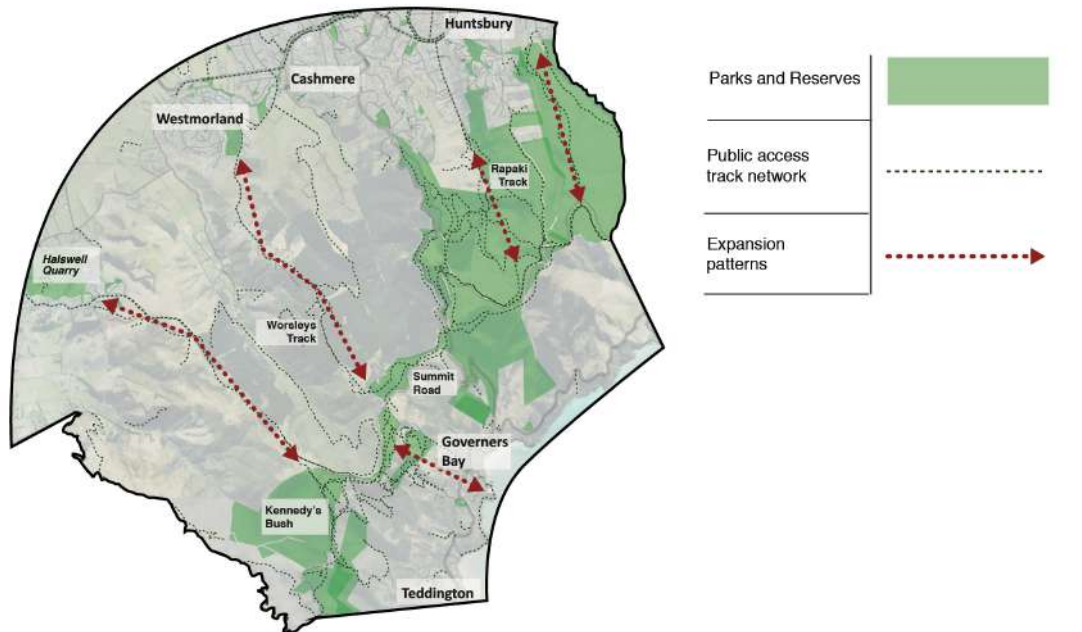


Figure 42 // Public access and recreation networks trajectory for Alternative Future A

Water networks trajectory

The water supply across the Port Hills will continue to be fed from the Canterbury Plains aquifers, which are stored in a series of reservoirs on the Port Hills mid flanks where they can gravity-feed specific properties (Christchurch City Council, 2003, 2017d; Rutherford, 2017). This system is complimented by a network of natural creeks running down the valley catchments (Swager, 2004). These are used in part for agricultural purposes but are likely to be increasingly restored and protected as natural waterways due to their hillside sensitivity (Christchurch City Council, 2003, 2016; Council, 2009). The water network will continue as a mid-flank tanked system, reliant on piping from the plains, and with a stream network feeding into the Heathcote catchment and Lyttelton harbour.

Water networks

Gradually expand to cater for increased demand, and restore natural waterways

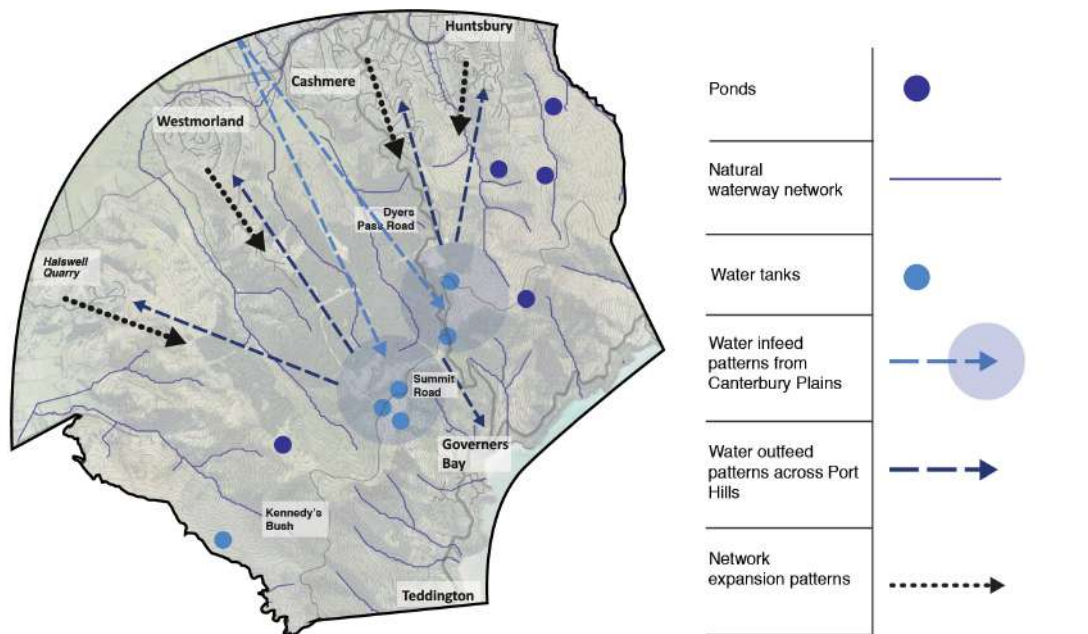


Figure 43 // Water networks trajectory for Alternative Future A

Pastoral farming trajectory

The Port Hills Rural zone recognises and values pastoral farming and a central component of the Port Hills 'backdrop' mosaic, which protects it from inappropriate subdivision, use and development (Christchurch City Council, 2016). However, the economic viability of pastoral farming in the Port Hills is waning, with low-productivity and difficult-to-access areas becoming increasingly overrun with scrub, or changing use (for example exotic forestry, or indigenous revegetation) (Orwin, 2008). This dynamic is well exemplified in the South West area plan (Council, 2009), and supports an overall trajectory towards the marginalisation of pastoral farming to the mid-flank, high-producing grassland areas.

Pastoral Farming
Gradual retreat from marginal areas

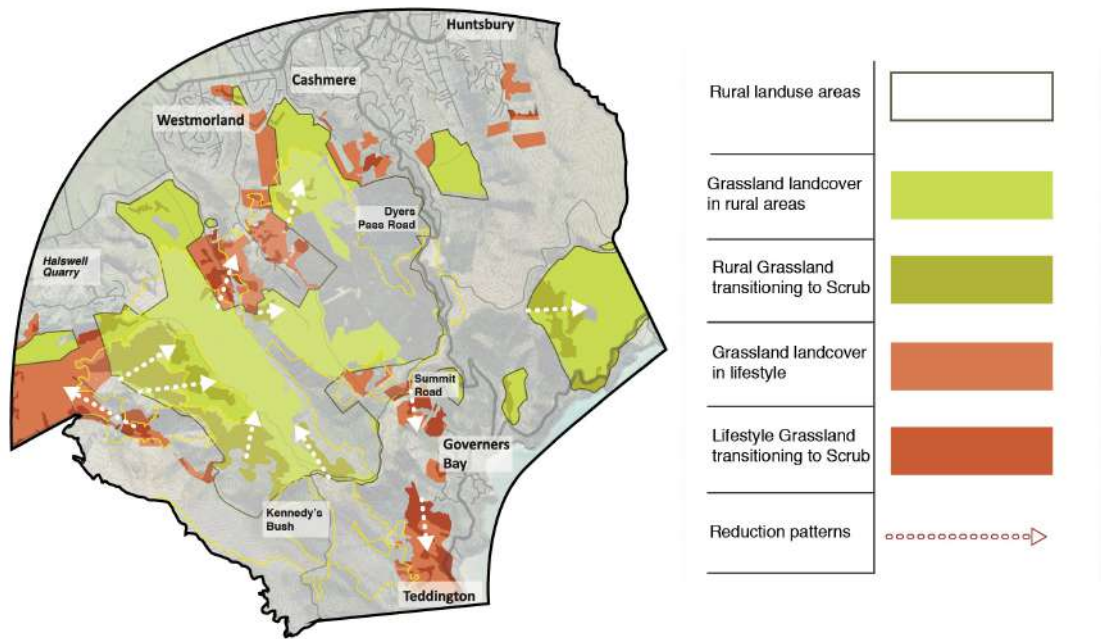


Figure 44 // Pastoral farming trajectory for Alternative Future A

Exotic forestry trajectory

Exotic forestry plantations across the Port Hills are a restricted discretionary activity, by which they are subject to certain standards around erosion and adverse landscape effects (Debbie Hogan, 2014; Selwyn District Council, 2010). Within this mandate, there is space and economic impetus for continued expansion (Christchurch City Council, 2016), for example the council support of commercial exotic forestry reinstatement after the Port Hill fires (Christchurch City Council, 2017c). The overall trajectory of exotic forestry is for its expansion across the marginalised mid and lower flanks of the Port Hills, especially west of Dyers Pass Road. In the adventure park which is largely covered by pine plantation forest extensively burnt in the 2017 fires, there are plans to significantly replant with natives (Fletcher, 2018).

Exotic Forestry

Restore and expand, especially south of Dyers Pass Road

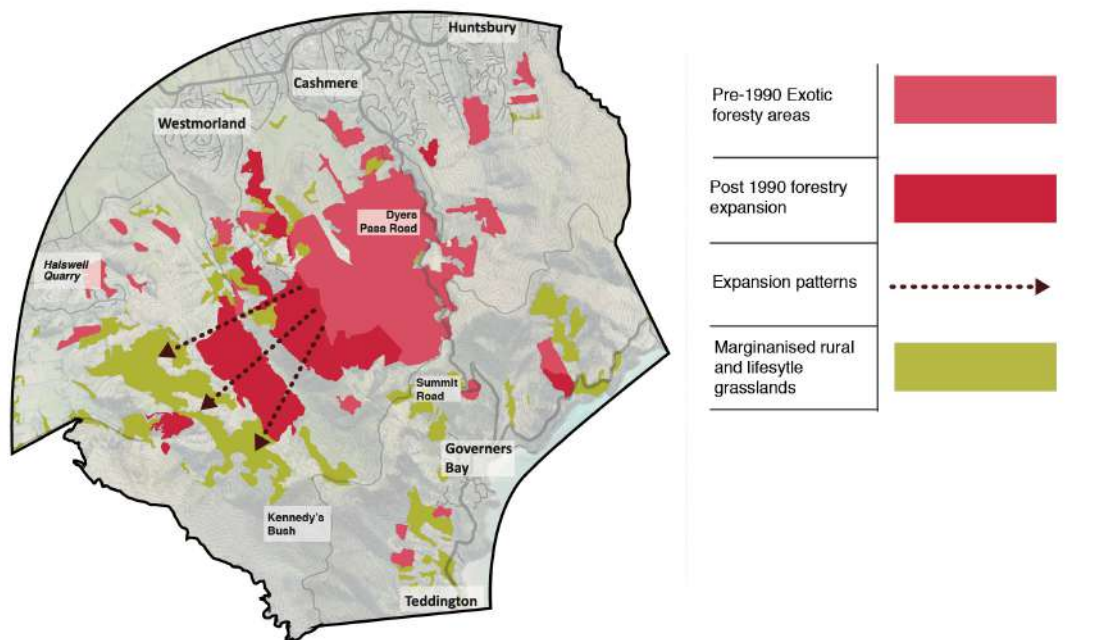


Figure 45 // Exotic Forestry trajectory for Alternative Future A

Indigenous revegetation trajectory

The pockets of indigenous biodiversity and ecosystems of the Port Hills are recognised and protected from the affects of subdivision, use or development (Christchurch City Council, 2016). Past success and future objectives see the growth of indigenous biodiversity quality, quantity and connectivity across the Port Hills, especially on public-owned land such as the reserves, public parks and the Summit Road Protection jurisdiction (Christchurch City Council, 2008a). However, extensive economic demand see the overall trajectory of indigenous biodiversity with marginalisation into pockets of less development-viable land within the valleys and upper reaches of the Port Hills.

Indigenous revegetation

Protect and incrementally expand

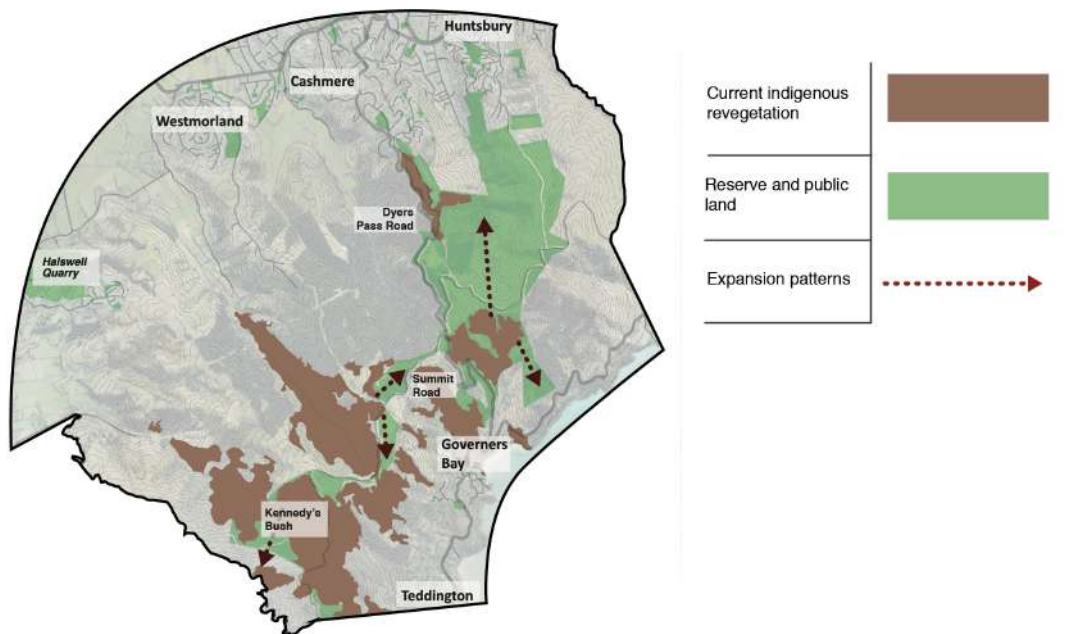


Figure 46 // Indigenous revegetation trajectory for Alternative Future A

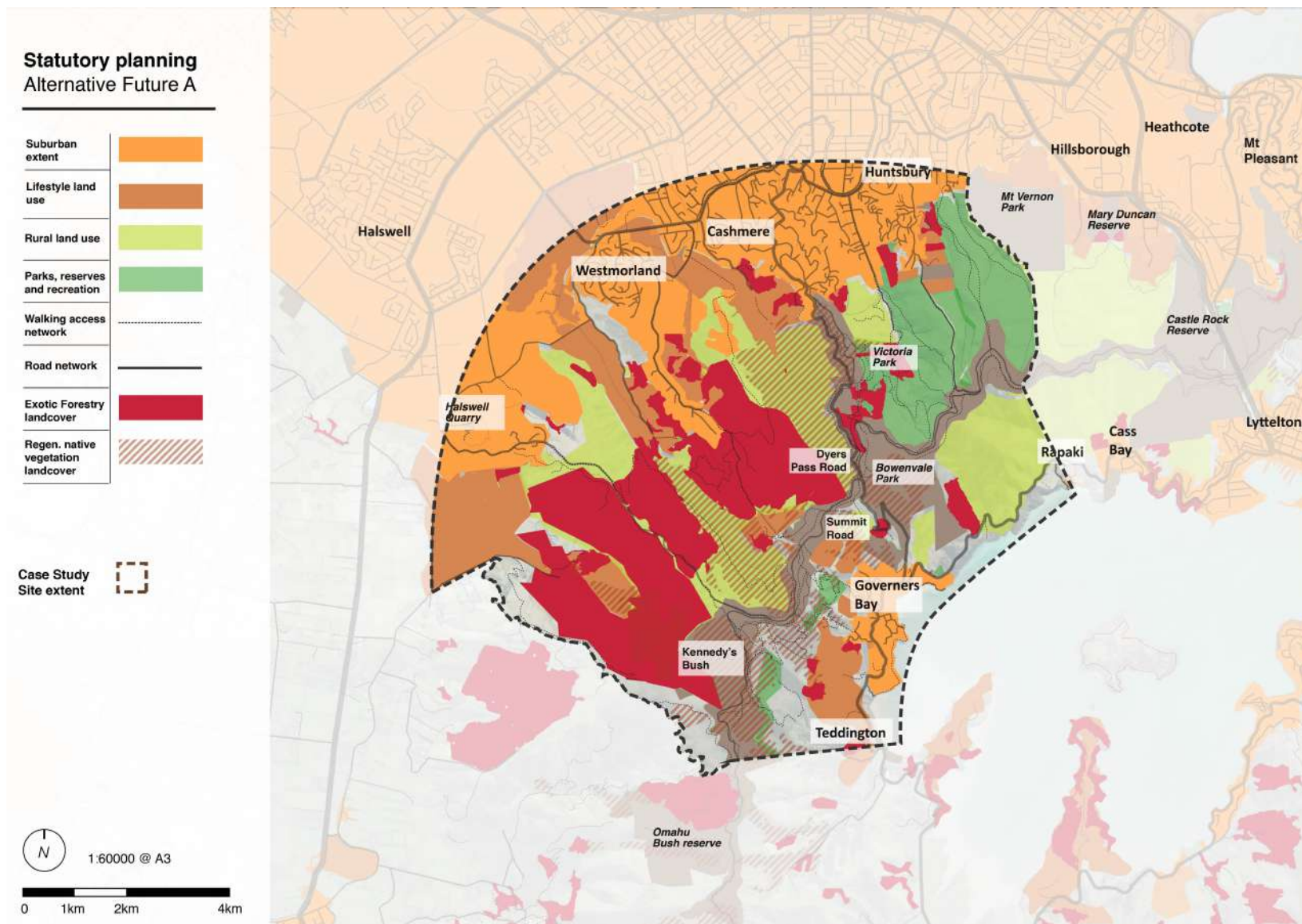


Figure 47 // Statutory Planning Alternative Future (A)

Alternative Future B – Scenic Preservation Port Hills

The scenic preservation movement has driven significant spatial changes throughout the Port Hills, and while components of the imperative have been integrated into statutory planning, it has a more focused prerogative to ‘preserve and protect the nature, beauty and open character of the Port Hills’.

Suburban residential trajectory

Through both formal and informal procedures, the scenic preservation movement continues to oppose subdivision throughout the Port Hills (Summit Road Society, 2003, 2017a). For example, 1999 environment court decisions limiting development on Worsleys Spur and up Cashmere Valley, were backed by wide-spread public support citing scenic preservation prerogatives of protecting rural character (Law, 2016). Overall, the scenic preservation movement is following a trajectory to limit residential development up the spurs, and entirely oppose development above the 160m contour line on the Port Hills mid-flanks (as well as the upper flanks/ridgeline) (Boffa Miskell, 2007; Summit Road Society, 2001, 2003).

Suburban residential

Retreat and contain development to lower flanks

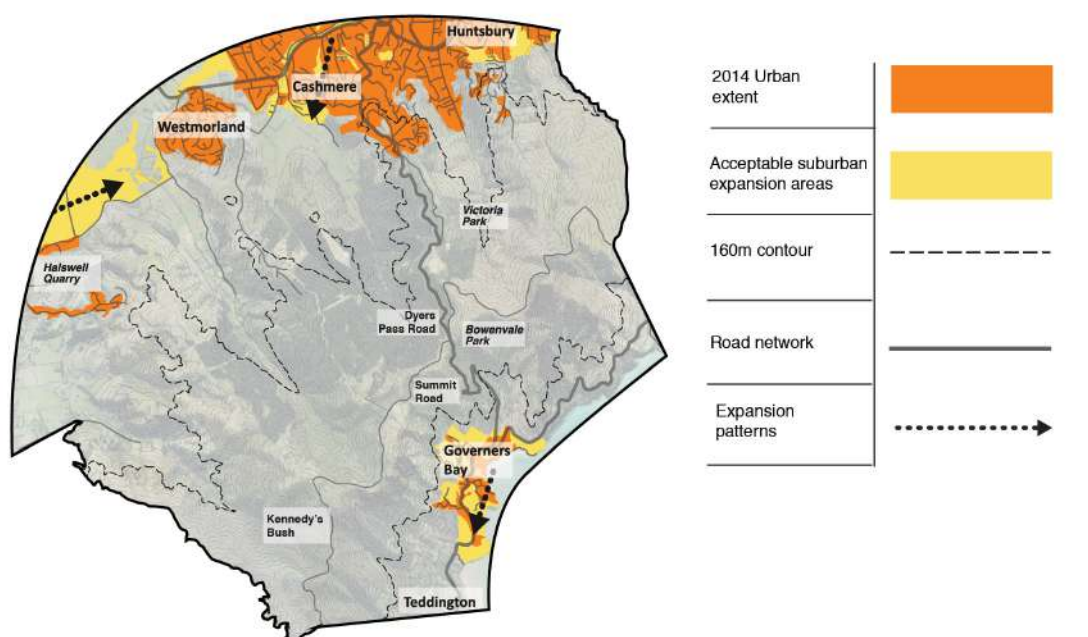


Figure 48 // Suburban residential trajectory for Alternative Future B

Lifestyle residential trajectory

Within this mandate however, the Scenic Preservation works alongside the need for development, by advocating to keep land parcels as large as possible (Law, 2016; Ogilvie, 2000). In this, they support a trajectory of low-flank lifestyle development in place of suburban residential.

Lifestyle residential
Controlled expansion on lower flanks

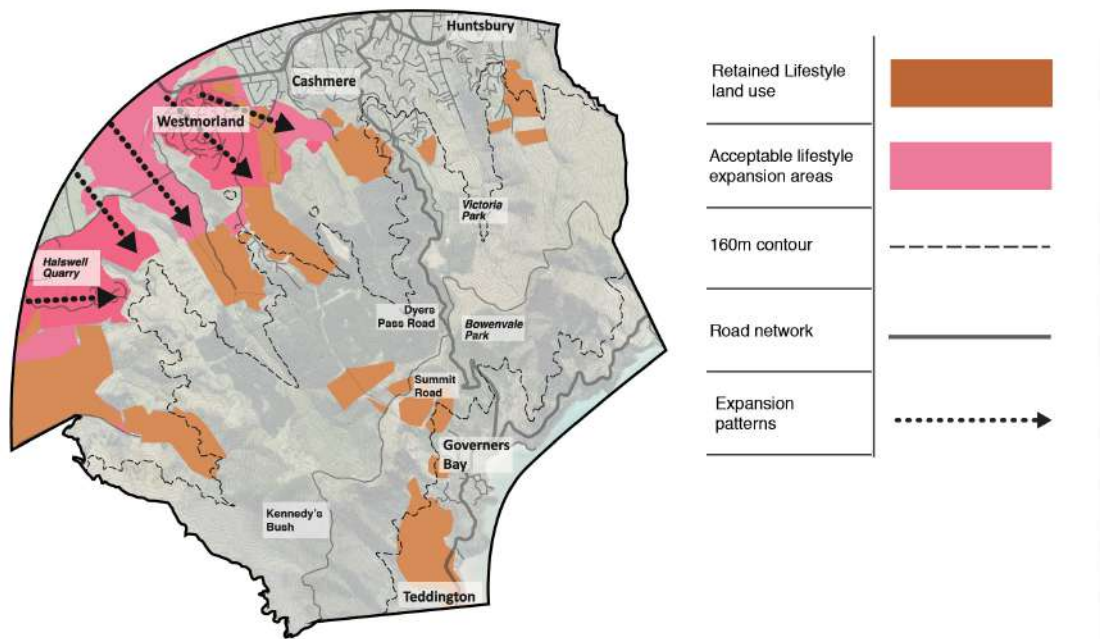


Figure 49 // Lifestyle residential trajectory for Alternative Future B

Roading and utility network trajectory

Roading networks throughout the Port Hills have been Harry Ell’s original vision to ‘help people enjoy the marvellous open space’ (Agar, 2015). However, there is now a need to the Port Hills landscape character. This culminates in opposition of visually disruptive patterns such as the chairlift of the Adventure Park which has created a linear structure from the base of the Port Hills to its ridge (Christchurch City Council, 2014a). The pace and character of vehicular access is also a concern, with the support of control vehicle use on the Summit Road (Cairns, 2015; Christchurch City Council, 2018b). There is a trajectory of protecting scenic vehicular access up to, and along the Summit Road, and the general regulation to protect the scenic quality and landscape character of the Port Hills.

Roading and utility network

Protection of scenic access along and up to ridges, yet controlled

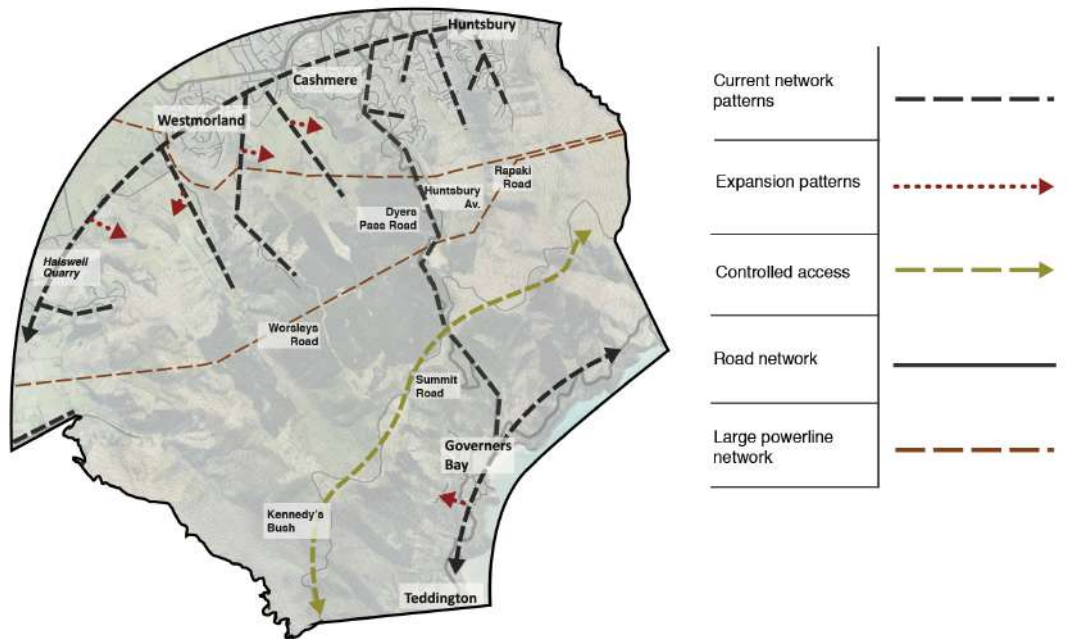


Figure 50 // Roading and utility network trajectory for Alternative Future B

Recreation and public access network trajectory

Recreation and public access are central tenants of the scenic preservation movement, fitting again into the 'enjoyment of the scenic Port Hills' mandate. This has driven the development of the extensive network of walking, biking and recreation routes. These have a particularly concentration along the upper scenic ridges, yet with various loop and access tracks stretching down the flanks (Ogilvie, 2000, p. 173; Orwin, 2008, p. 42). The scenic preservation movement continues along a trajectory of expansion and maintenance of this network, kept in check by the same tensions as vehicular accessibility with regulated visual and environmental effects.

Public access and recreation networks

Maintain and expand along and up to the Scenic ridges, yet controlled

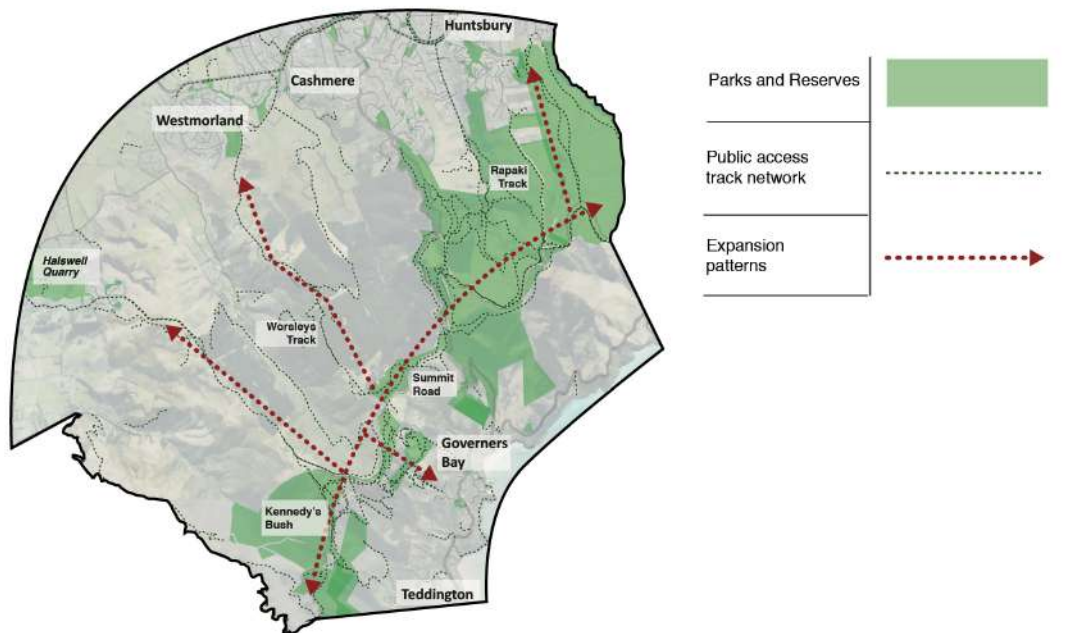


Figure 51 // Public access and recreation networks trajectory for Alternative Future B



Figure 52 // A track meandering across an upper ridge of silver tussock, with a scenic outlook of Christchurch and the Southern Alps (Hewgill, 2009)

Water networks trajectory

The scenic preservation movement is aligned through biodiversity goals to the protection and management of the valley stream systems throughout the Port Hills (Ogilvie, 2000). However, the key focus for water networks is the scenic outlook over Lyttelton Harbour (Summit Road Society, 2017b). Therefore, the trajectory shows continued support and management of the stream

catchment system, with retention of the water supply networks to cater for limited residential expansion. At a broader scale, public access will be protected to areas with water-outlooks, which within the case-study site are limited to eastern views over Lyttelton Harbour.

Water networks
Strengthen water outlooks, and restore natural waterways

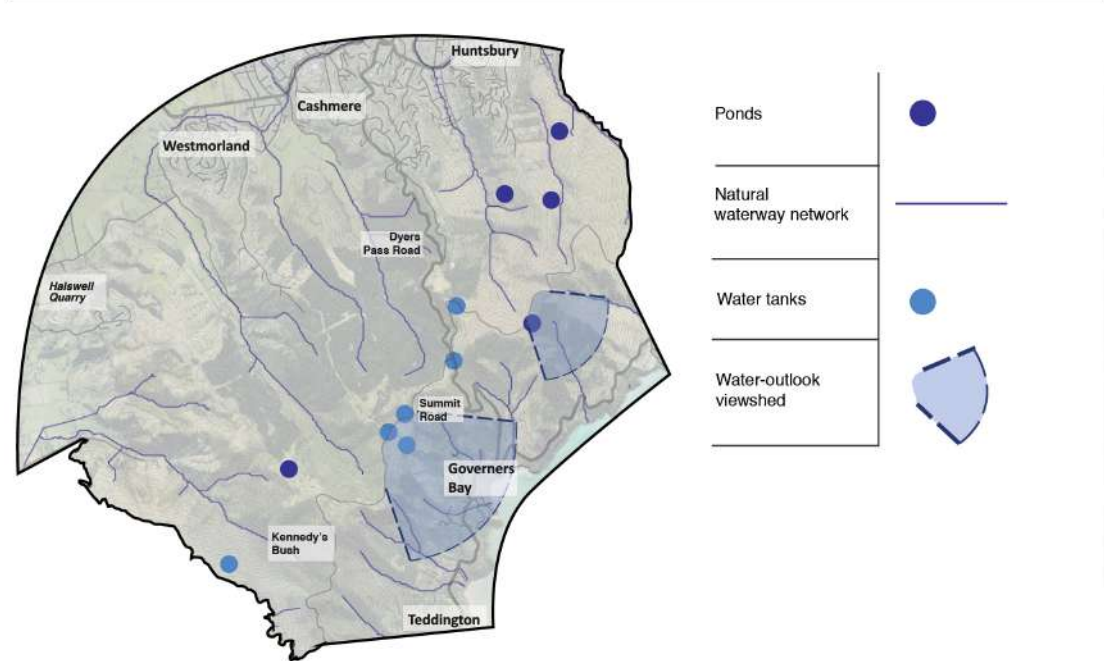


Figure 53 // Water networks trajectory for Alternative Future B

Pastoral farming trajectory

Scenic Preservation has a nuanced relationship with pastoral farming on the Port Hills, with recognition and value given to the open space patterns it contributes to the over landscape (Summit Road Society, 2017a). However, farming is becoming increasingly less economically viable, setting the scene for marginalised farmland to be repurposed for other scenic preservation prerogatives such as public access or indigenous regeneration (Ogilvie, 2000). Overall, the trajectory of farming within the scenic preservation movement is towards its retention on the mid and lower flanks, with diversification on the marginally arable upper flanks, and south-west valleys.

Pastoral Farming

Retreat from marginal areas, and repurpose as native revegetation

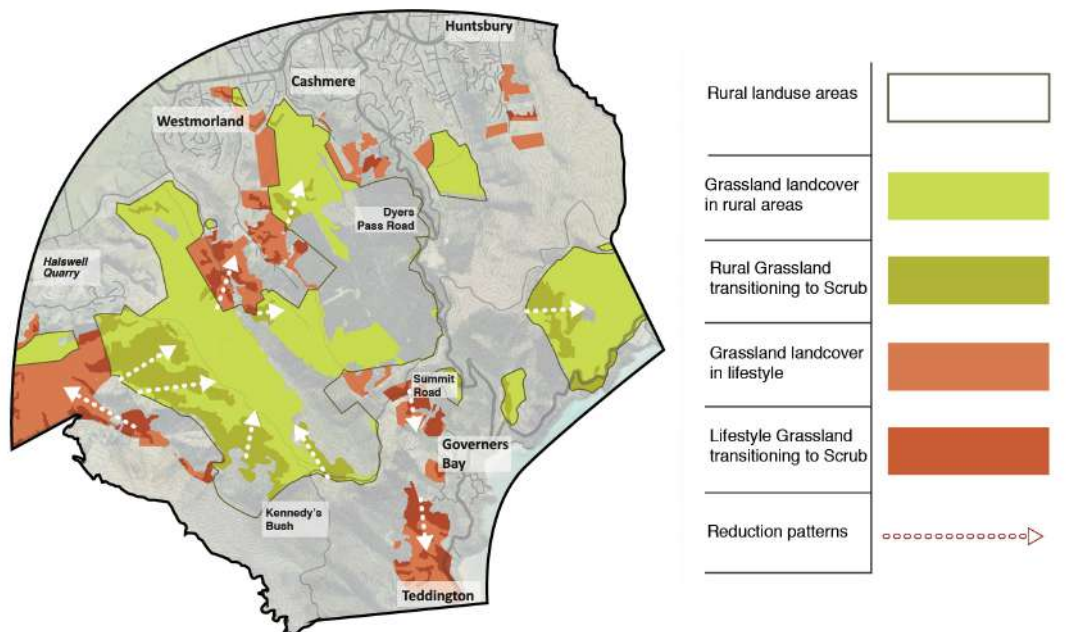


Figure 54 // Pastoral farming trajectory for Alternative Future B

Exotic forestry and Indigenous revegetation trajectories

Exotic forestry is considered a major issue by the Scenic Preservation movement, who would like to see plantations replaced with native forest, and prohibit *Pinus radiata* on the Port Hills (Orwin, 2008). Exotic Forestry is seen as having a very significant adverse affect on the character of the landscape, and wilding pines to threaten indigenous biodiversity (Boffa Miskell, 1985). As this entails, indigenous revegetation is a central tenant of Scenic Preservation and envisions that by 2023 'the landscapes of the Port Hills will range from large tracts of linked native forest cover in the south-west to open tussock lands and forested gullies in the east' (Orwin, 2008). Overall, scenic preservation is following a trajectory of removing and prohibiting exotic plantation forestry, and using this land to extend and connect regenerating indigenous vegetation, which is also being extended throughout all marginal areas of the Port Hills (Rob Greenaway & Associates, 2004).

Exotic Forestry

Retreat and generally prohibit

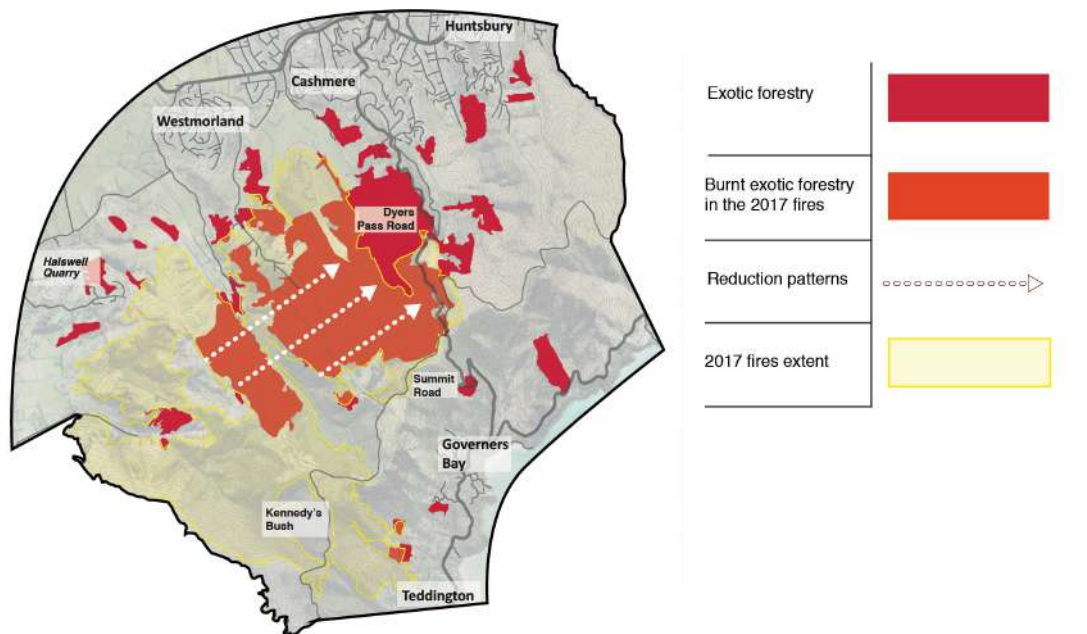


Figure 55 // Exotic forestry trajectory for Alternative Future B

Indigenous revegetation

Extensive expansion of southwest native forest-cover, and in eastern valleys

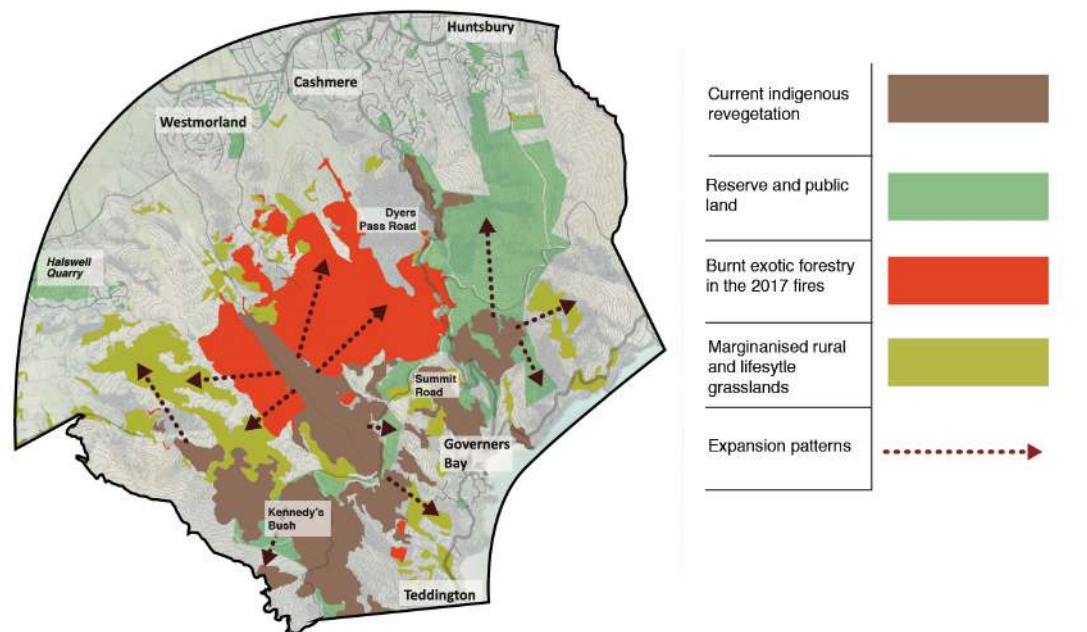


Figure 56 // Indigenous revegetation trajectory for Alternative Future B

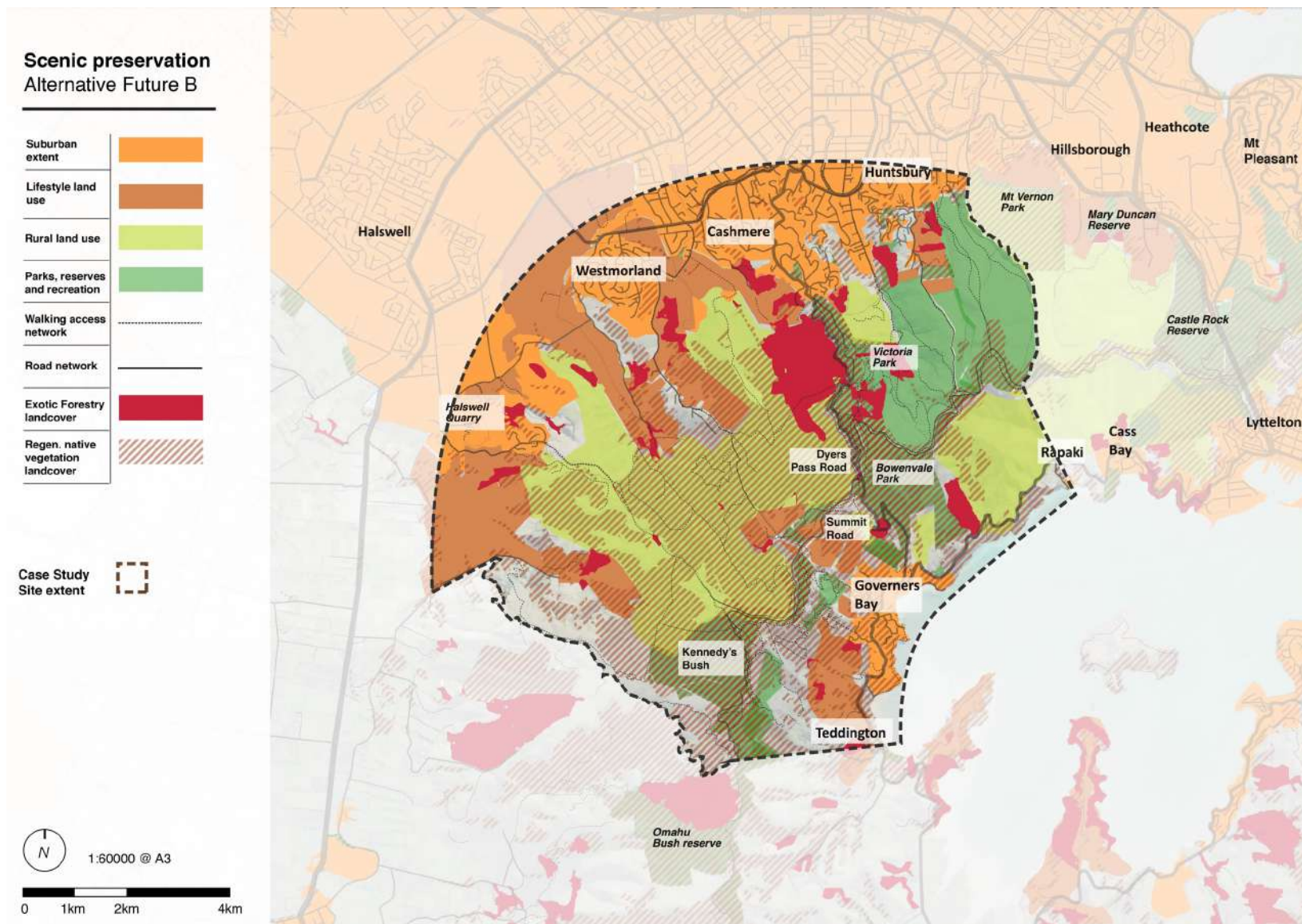


Figure 57 // Scenic Preservation Alternative Future (B)

Alternative Future C – Wildfire Managed Port Hills

Unlike the others, this alternative future is based on spatial planning trajectories not intended for the Port Hills. Therefore, the following trajectory explanations focus more on how the logic behind the exemplar spatial planning approaches are relevant and applicable to the case-study site.

Suburban residential

Suburban residential development around the base of the Port Hills forms a definite peri urban boundary between urban and wildlands, and generally, the longer this boundary extends the higher the associated wildfire threat (Gill, 2005). Therefore, this threat can be managed by simplifying and straightening the peri-urban boundary. In the case study, a linear low-flank peri-urban boundary could be achieved by taking a consolidating infill approach to development on the lower flanks (Rasker & Barrett, 2016; Syphard et al., 2013), restricting extensive residential growth up the spurs which is framed by hazardously vegetated valley walls (Bhandary & Muller, 2009). This boundary still holds a wildfire threat, so can be buffered with lower-threat landuse and landcover categories discussed below. Such buffers have been widely applied internationally through a 500-meter zone of low-lying fuels to avoid ember-throwing canopy fires, and a two-kilometer low-flammability land-use zone to minimize chances of fires reaching residential areas (Gill, 2005; A. Smith et al., 2016). At 2km, the largest zone covers the Port Hills. At a smaller scale, a 50m zone involves the design of buildings and properties, and while this is largely affected though land management, development controls could allow planners to also affect this zone.

Suburban residential

Consolidate low-flank belt and buffer

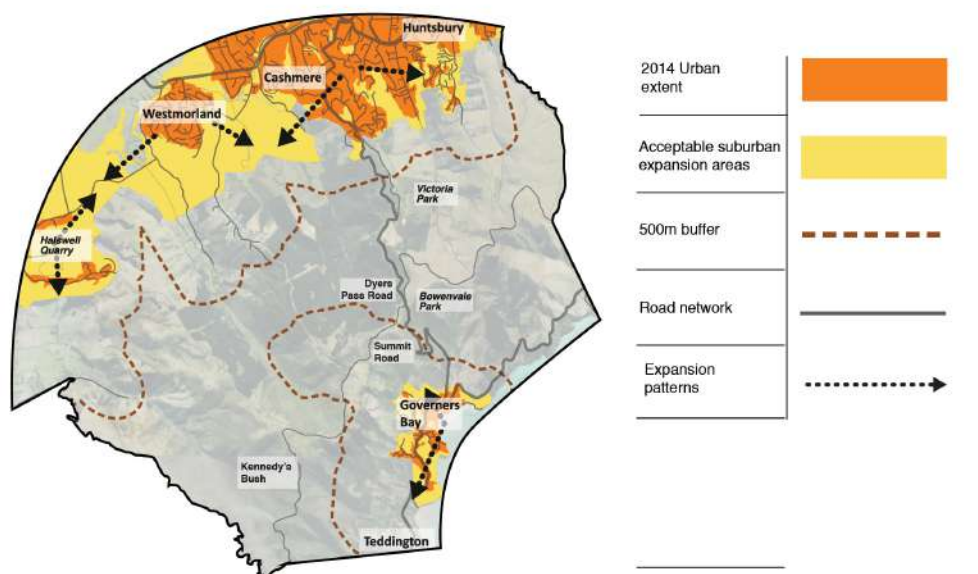


Figure 58 // Suburban residential design for Alternative Future C

Lifestyle residential

Lifestyle blocks form intermixed peri-urban pockets, which also extend the sinuosity of interface, and while low-density, non-rural residents bring specific wildfire threat such as under-managed vegetation (FENZ, 2017a; Hart & Langer, 2011). Therefore, this wildfire threat could be managed by retreating from the 2017 fire-affected residential properties, and intensively managing and buffering those which were not.

Lifestyle residential *Retreat and buffer*

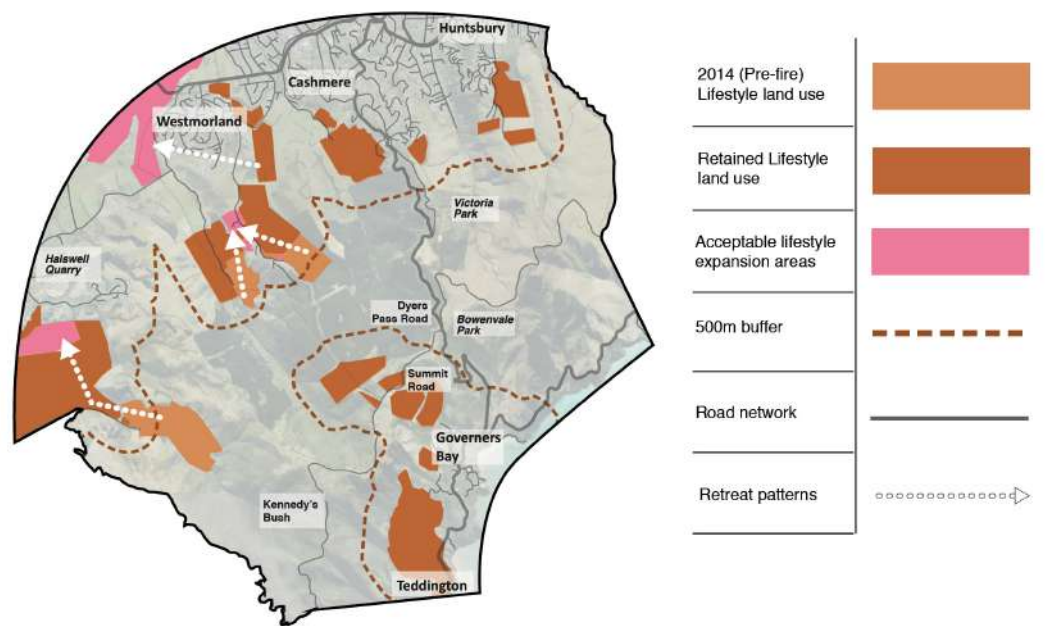


Figure 59 // Lifestyle residential design for Alternative Future C

Roading and utility network

The layout and design of roading networks are an important component for wildfire management (Klein, 2017). There are four key ways in which roads affect wildfire management and threat: providing evacuation routes for wildfire-threatened inhabitants (Klein, 2017), providing access for emergency response services (Bhandary & Muller, 2009), acting as fire breaks (R. Smith, 2009), and lastly increasing wildfire threat by increasing the spread of ignition sources (Gill, 2005; Gucinski, 2001; Hart & Langer, 2011). This final aspect is reflected in utility networks such as powerlines, which similarly increase the spread of ignition sources (Hart & Langer, 2011). For effective wildfire management, one road can service as an access and egress route for up to 100 homes, two for 100-600 homes, and three for over 600 (Klein, 2017). Roads with a 15m width (not necessarily trafficable) can effectively act as firebreaks (R. Smith, 2009), and would be located around areas of high threat. The risk associated with public vehicular access is especially relevant in a New Zealand

context, where 17% of wildfires are caused by vehicles, arson sites often located in easily accessible areas, and powerline networks and their associated systems present a significant national wildfire risk (Hart & Langer, 2011). Wildfire management could therefore be imagined within the case-study by extending vehicular access up the marginal adjacent routes such as Worsleys Road, while restricting this adjacent public access to Dyers Pass road and expanded low-flank arterial roads linking residential areas. Arterial roads could be buffered to serve as fire-breaks to restrict north/south movement of wildfires, while the Summit Road and national transmission line serve as firebreaks for east/west movement.

Roading and utility network

Expanded patchwork of firebreaks/access, with controlled public access

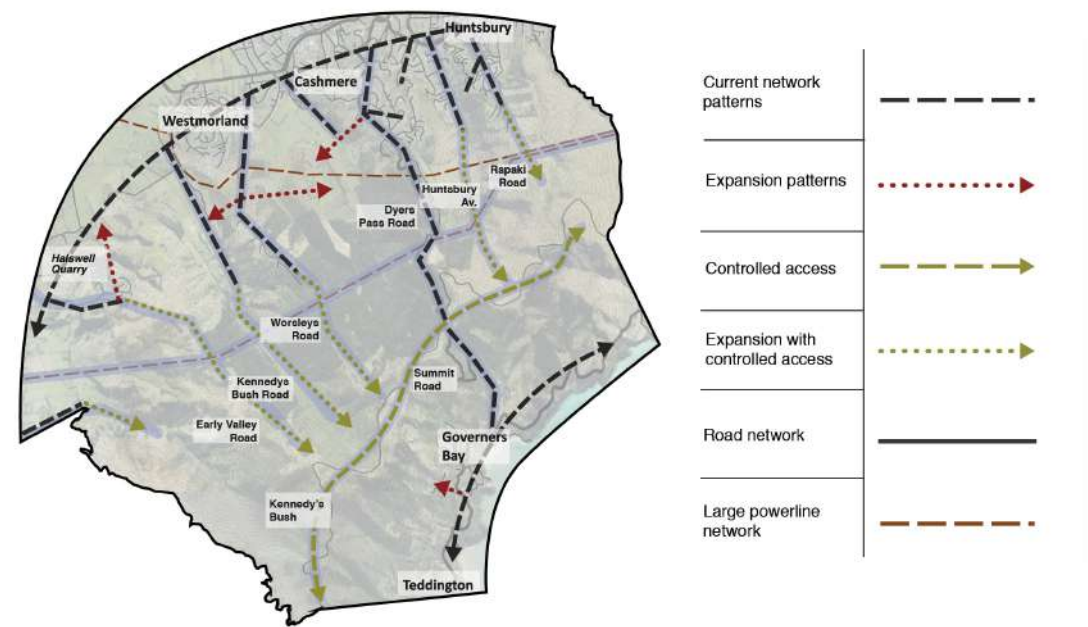


Figure 60 // Roading and utility network design for Alternative Future C

Recreation and public access network

Similar to vehicular access, general public and recreational access allows for increased human activities within fuel loaded areas, bringing an inherent wildfire risk with the wide network that stretches throughout the Port Hills (Hart & Langer, 2011). However, a sense of stewardship in recreationists has been found to create early-alert networks, with users effectively identifying and reporting wildfires (Hogans, 1979; Rasker & Barrett, 2016). While much of public and recreational network wildfire threat is managed through land management and social development, these factors support a scenario with shorter public access routes alongside the upper summit road ridgeline, giving outlook over the mid and lower flanks of the hills while minimising the extent of the network.

Public access and recreation networks

Sustained recreational public access, focus on short upper ridge routes

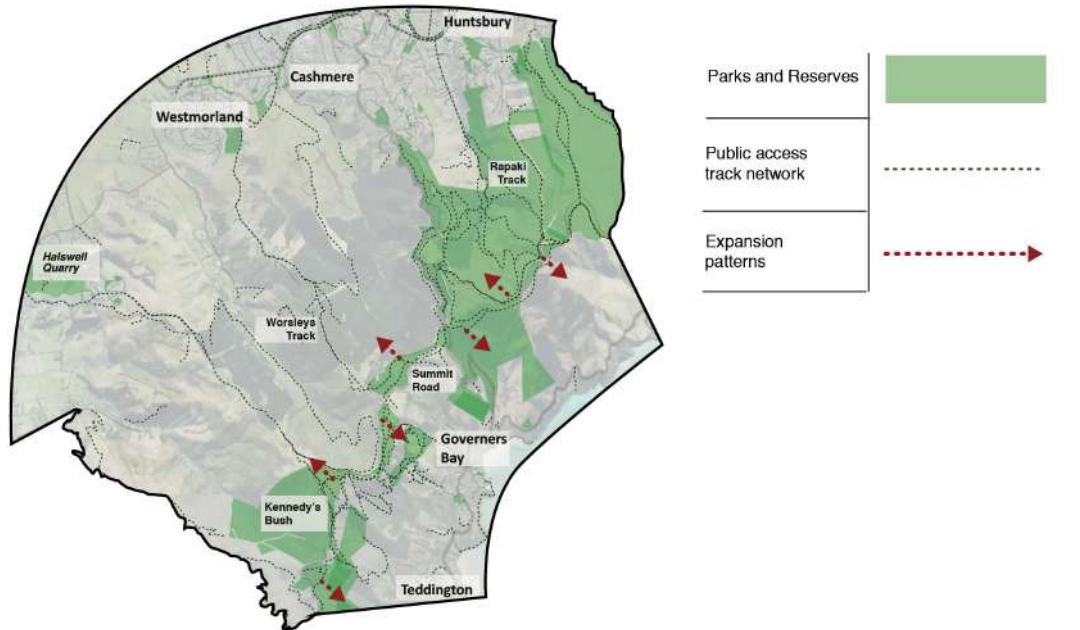


Figure 61 // Public access and recreation networks design for Alternative Future C

Water networks

In his 2004 thesis on water resources for fire-fighting in the Port Hills, J. Swager evaluates the Port Hills for water accessibility (Swager, 2004). Swager manages wildfire threat by extending 2km buffers around accessible water sources, and identifies a gap around the Kennedy's Bush area. Secondly, the widely-spread and interrelated nature of the water supply and natural stream networks mean they are particularly susceptible to the affects of wildfire (Christchurch City Council, 2017c). The stream network could be buffered by low-flammability fuels consistent with riparian planting, while the water supply network could follow the adjacent roads discussed above as 15m buffered firebreaks.

Water networks

Expand network of accessible water sources, and restore natural waterway systems

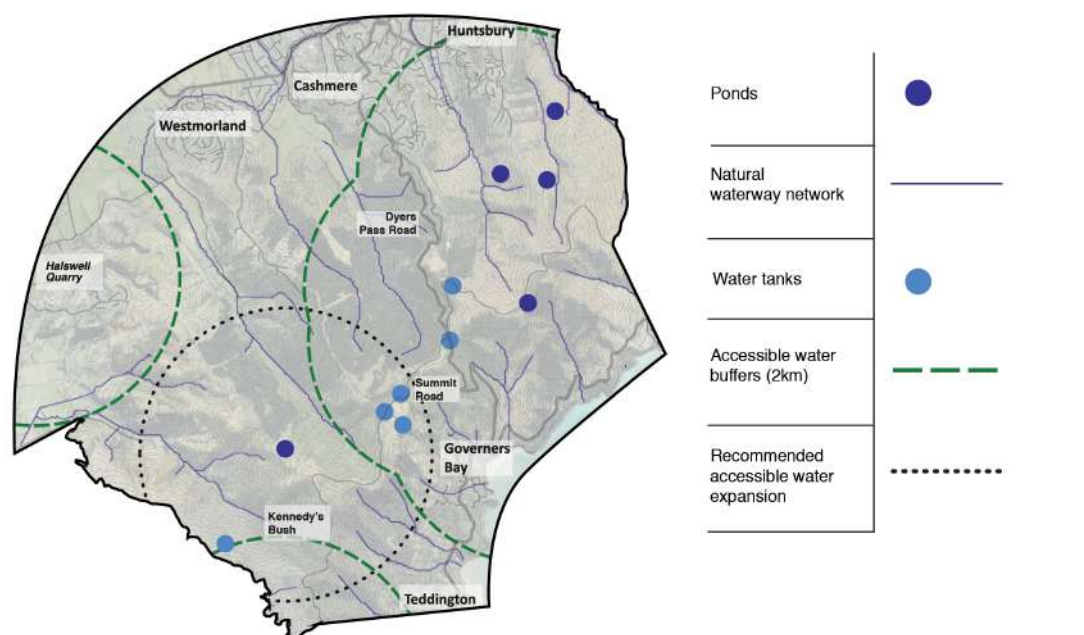


Figure 62 // Water network design for Alternative Future C

Rural pastoral trajectory

Pastoral farming entails a range of wildfire threats, the seasonal fuel-loading of pasture grass, the significant fuel loading with scrub reverting-pasture, and the high-risks activities associated with farming such as land-clearance fires (Bhandary & Muller, 2009; Doherty et al., 2008; Gill, 2005). This is deeply relevant to a New Zealand context where 20% of Wildfires are caused by land-clearance, while these fires resulted in 47% of land-area burnt (Hart & Langer, 2011). In the case-study site, this would be managed by retreat pastoral farming from marginal upper and mid flanks, down to productive lower slopes where higher land management standards can be maintained. Within this high-management capacity, pasture is a low-lying hazard which can work as a fuel buffer from canopy fires, though this highlights issues with lifestyle properties and the declining economic viability of farming.

Pastoral Farming

Retreat from marginalised areas, and manage intensively

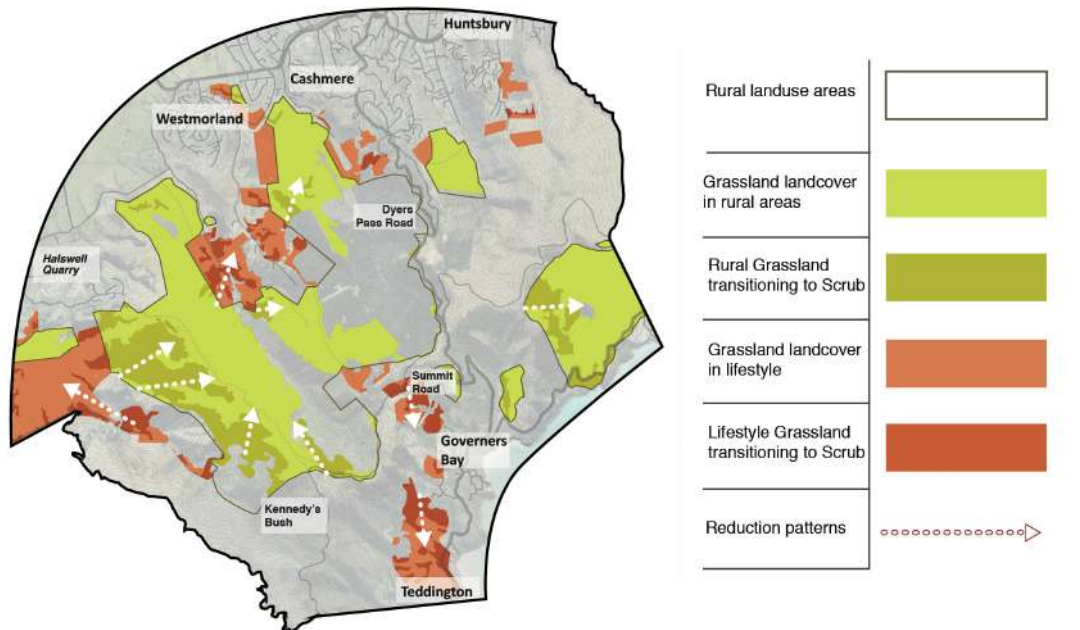


Figure 63 // Pastoral farming design for Alternative Future C

Exotic forestry trajectory

Exotic forestry, and specifically *Pinus radiata* plantations are an extensive Port Hills land use which presents a significant peri urban wildfire threat. While the stem flammability of *Pinus radiata* is moderate (Wyse, Perry, & Curran, 2017), dead plant material on the ground below and in their canopies present a significant risk, with easily ignitable fuels and a composition that supports crown fires (Gill, 2005; Wyse et al., 2017). Internationally, pine plantations are a central concern for spatial planning to manage wildfire threat (Gill, 2005; B. Norman, Weir, Sullivan, & Lavis, 2014; Rasker & Barrett, 2016; Sturtevant & Jakes, 2010). The risk with the overlap of pine plantations with public access, and their proximity to residential areas has long been a public concern in the Port Hills (Hart & Langer, 2011), perhaps due to events such as the 1935 Victoria Park fire. Nationally, pine plantations have had a significant role in many major New Zealand wildfires (G. Pearce & Alexander, 1994). Within the case-study, this could be managed by retreating exotic forestry from the extensive areas burnt during the 2017 fires, halting any further development of high-flammability exotic forestry, and retreating exotic forestry from the urban boundary.

Exotic Forestry

Retreat from burnt areas and buffer from urban edge

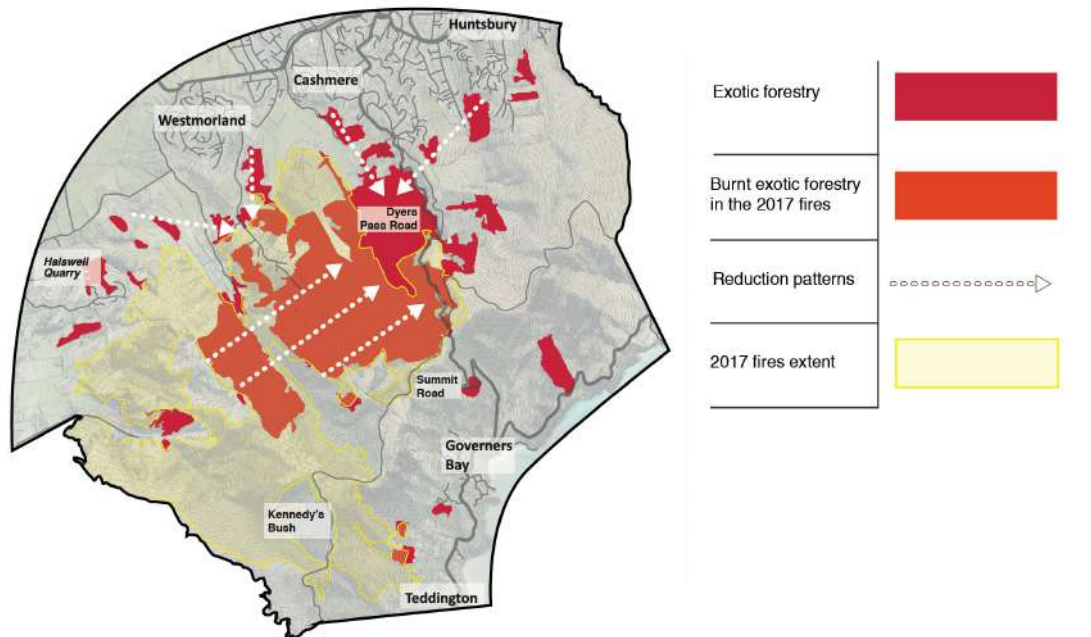


Figure 64 // Exotic Forestry design for Alternative Future C

Indigenous revegetation trajectory

Indigenous revegetation presents both wildfire management opportunity, and wildfire threats. A significant yet transitional threat is the popular succession approach to indigenous revegetation in the Port Hills, which involves supporting very high-flammability scrub such as Kanuka, Manuka and Gorse to act as nursery plants for broadleaf forest saplings (Summit Road Society, 2017d; Wyse et al., 2017). However, once with an established canopy, broadleaf forest can act as an effective 'greenbelt' landcover (Curran et al., 2018; A. Smith et al., 2016). In the case study, this is an effective and extensive approach to the larger zone buffer for the urban.

Indigenous revegetation

Create network of broadleaf greenbelts with general revegetation

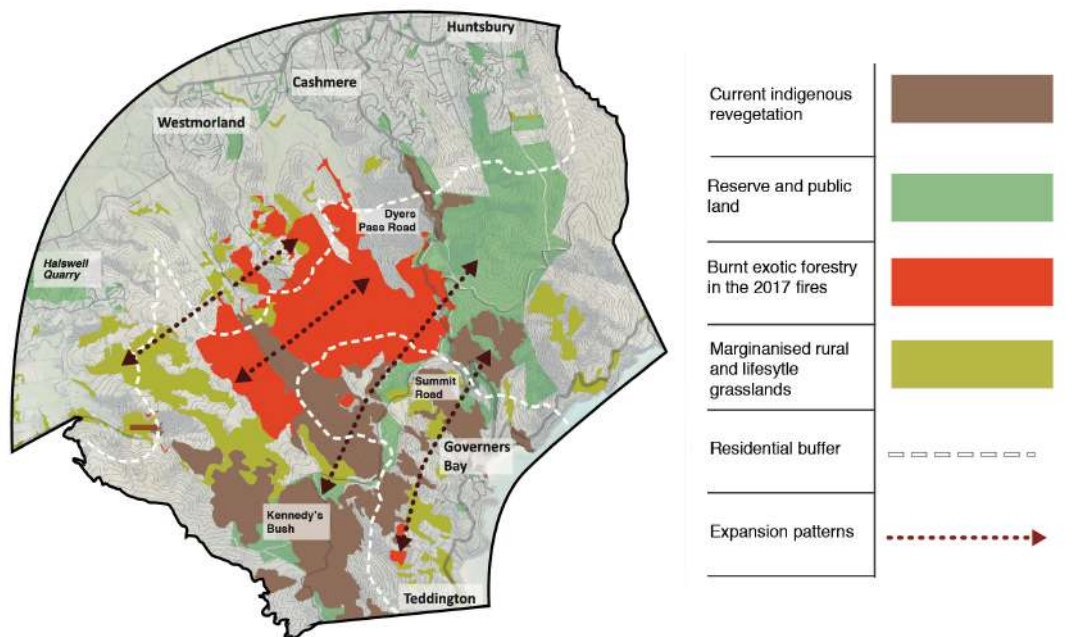


Figure 65 // Indigenous revegetation design for Alternative Future C

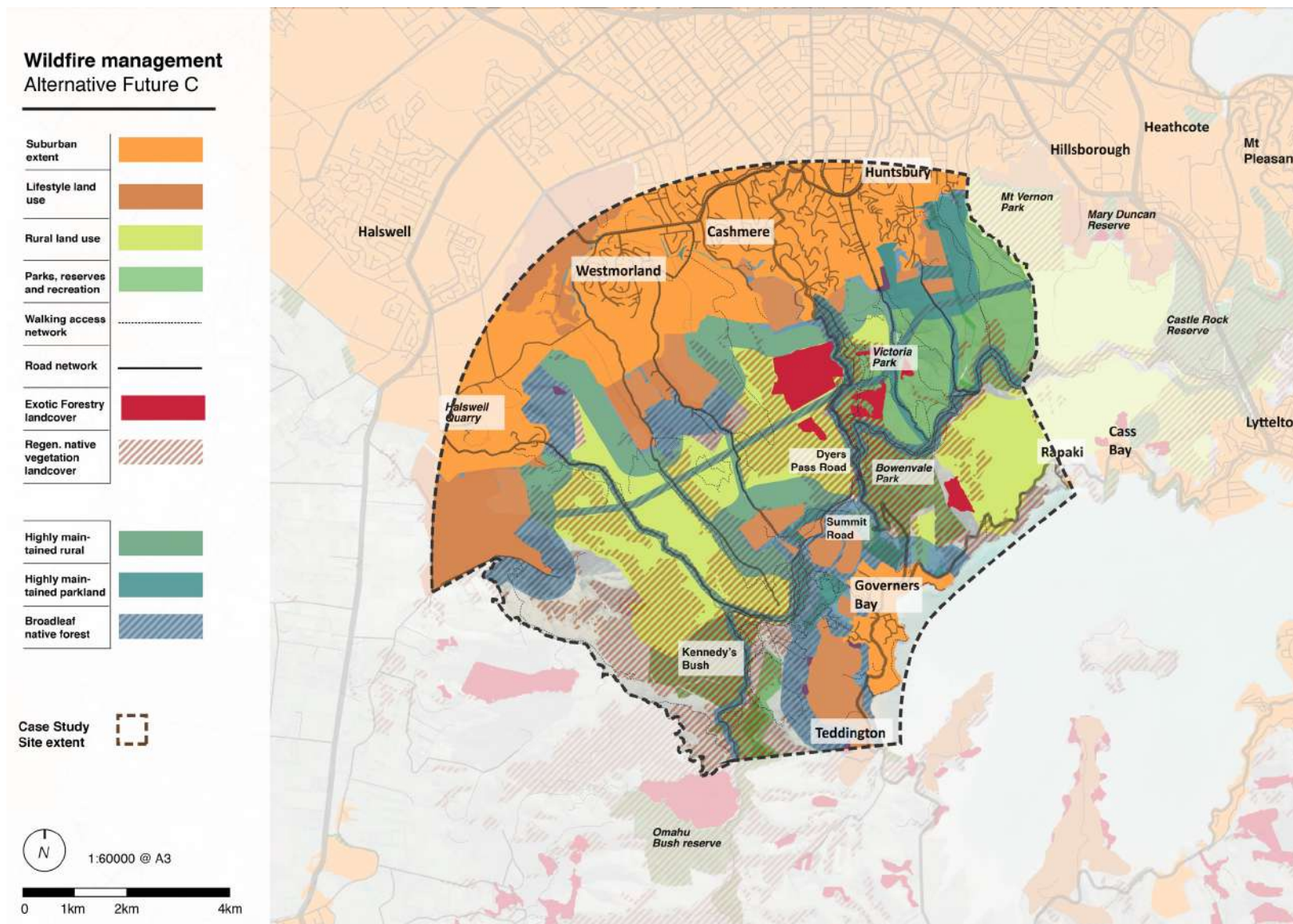


Figure 66 // Wildfire Managed Port Hills Alternative Future (C)

Comparison and discussion

Five types of landscape change were observed across the three alternative futures: retreat, obsolescence, stagnation, strengthening, and creation. This set of terms can be used to show the direction of change intended for each landscape category by each alternative future, and with the alternative futures aligned the similarities and differences in landscape change draws attention to the implications and opportunities for current planning directives for the Port Hills. These contrasts between the alternative futures and their associated landscape changes are shown below in Figure 67, with the legend on the page opposite.

	Alternative Future A Statutory Planning	Alternative Future B Scenic Preservation	Alternative Future C Peri Urban Wildfire Managed
Suburban residential	Leapfrog expansion on lower flanks, especially on spurs and south of Dyers Pass Road	Retreat and contain development to lower flanks	Consolidate low-flank belt and buffer
Lifestyle residential		Controlled expansion on lower flanks	Retreat and buffer
Roading and utility networks	Protect scenic vehicular access, expand to cater for residential demand, and control Summit Road access	Protection of scenic vehicular access along and up to ridges, yet controlled	Improved network of firebreaks/access, with restricted public access
Recreation and public access networks	Maintain and diversify	Maintain and expand along and up to the Scenic ridges, yet controlled	Sustained recreational public access, focus on short upper ridge routes
Water networks	Gradually expand to cater for increased demand, and restore natural waterways	Strengthen water outlooks, and restore natural waterways	Expand network of accessible water sources, and restore natural waterways
Rural pastoral	Gradual retreat from marginal areas	Retreat from marginal areas, and repurpose as native revegetation	Retreat from marginalised areas, and manage
Exotic plantations	Restore and expand, especially south of Dyers Pass Road	Retreat and generally prohibit	Retreat from burnt areas and buffer from urban edge
Indigenous revegetation	Protect and incrementally expand	Extensive expansion of southwest native forest-cover, and in eastern valleys	Create network of broadleaf greenbelts with general revegetation

Legend

Retreat - Designed reduction	Obsolescence - Gradual reduction	Stagnation - Minor changes only	Strengthening - Moderate expansion	Creation - Significant expansion
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Figure 67 // Comparison chart of alternative futures and their landscape change trajectories

The following paragraphs discuss these similarities and differences across the alternative futures in more detail.

The key differences across the alternative futures are within residential landuses (both suburban and lifestyle), and with exotic plantations. In these areas, there are directly opposing directions of landscape change. Specifically, the statutory planning and scenic preservation trajectories for residential land use both contrast heavily with the wildfire managed approach of high-density consolidation (infill) development. Both statutory planning and scenic preservation propose the increased sinuosity and length of the peri-urban edge (though to varying degrees), with statutory planning working towards fingers of infill development and the associated values and risk extending onto the Port Hills rural and its fuel-rich flanks. Scenic preservation supports the same effect yet restricted below the 160m contour, and with large-lot lifestyle residential development. With regards to exotic plantations, statutory planning supports the re-instatement of silviculture assets and interests in the area, while both the wildfire managed future and the scenic preservation scenario would both see a significant reduction of exotic plantations.

The key similarities across the alternative futures are water networks and rural pastoral areas. More specifically, all alternative futures see a strengthening of water networks, while all see the obsolescence of marginalised rural pasture land on the upper flanks.

Roading and utility networks, along with public access networks are moderately aligned across the alternative futures. The only differences being that while statutory planning would see an active strengthening of these networks, scenic preservation and wildfire management would see a more stagnated management approach. Similarly, with regards to indigenous revegetation, scenic preservation and wildfire management are aligned as expansion which varies only moderately from statutory planning's strengthening of indigenous revegetation. However, spatially scenic preservation and wildfire management do significantly differ on this expansion, with wildfire management focusing on corridors of green-break broadleaf forest.

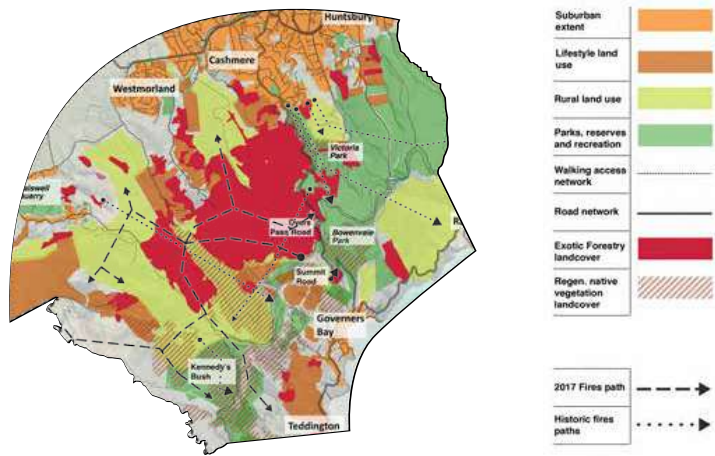
Implications and opportunities for spatial planning to manage Port Hills wildfire threat

The comparison of alternative futures explored above highlights key implications and opportunities for managing Port Hills wildfire threat through spatial planning. These are summarised below, and extended on to relate to Figure 68, which shows the patterns of historic wildfires in the Port Hills, overlaid onto the three alternative futures and illustrating these implications and opportunities within this specific event:

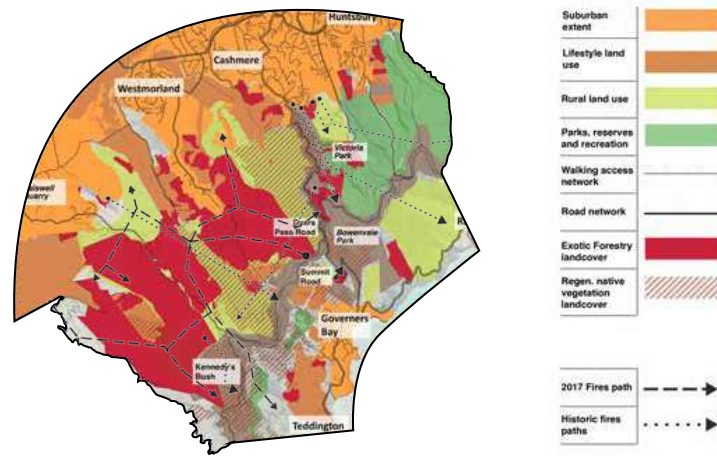
- There are significant wildfire threat implications with continued leap-frog suburban and lifestyle residential expansion, particularly with sinuous ridgeline developments working to extend the length of the peri-urban boundary. In Figure 68, the historic wildfire patterns significantly overlap with residential areas within both the statutory planning and scenic preservation futures. This illustrates an increased risk and threat to values, and in the case of scenic preservation a further increase of hazard through lifestyle properties.
- The significant implications with having exotic forestry on the Port Hills, particularly with the statutory planning intentions for re-instatement significant areas of pine plantation. This implication is illustrated in Figure 68, where pine forest in the statutory planning future densely overlaps with the historic wildfire patterns suggesting areas such as Victoria Park which if replanted with pine could play a significant role in future wildfires. Therefore, the 370 hectares of burnt forestry from the 2017 Port Hills fires can be seen as an 'blank-slate' opportunity for changes in landuse and landcover to better manage the Port Hills wildfire threat.
- There is a significant opportunity to manage wildfire threat by repurposing the extensive rural/peri-urban areas opened up with economic marginalisation of pastoral farmland on the Port Hills.
- Finally, there is a significant opportunity for focusing the well-supported expansion of Port Hills indigenous re-vegetation into a network of highly-managed buffers and broadleaf greenbelts along current network patterns, which could effectively buffer high-risk activities, isolate hazardous fuels, and protect values by intercepting wildfires.

Overall, the comparison of the alternative futures show that the current landscape changes occurring in the Port Hills through statutory planning and to a lesser degree scenic preservation, are perpetuating the wildfire threat in the area. Furthermore, spatial planning has a clear potential to manage the Port Hills' wildfire threat that was brutally showcased in the 2017 Port Hills Fires, with the post-disaster spatial planning opportunities of policy windows and a blank-slate landscape left uncatalyzed.

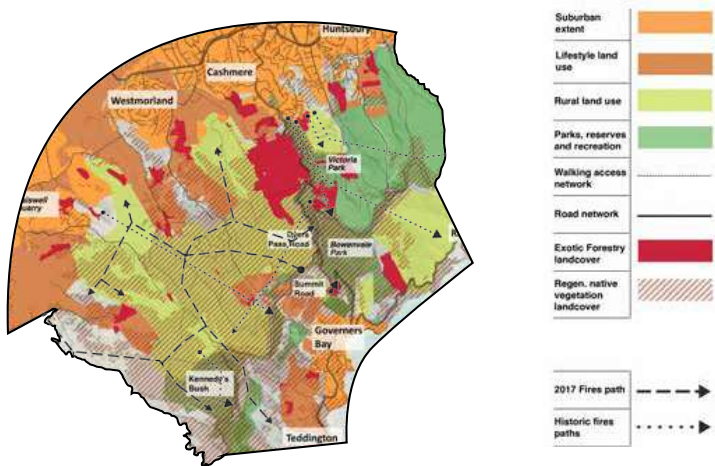
Case study current site with wildfire history overlay



Statutory Planning alternative future with wildfire history overlay



Scenic preservation alternative future with wildfire history overlay



Wildfire managed alternative future with wildfire history overlay

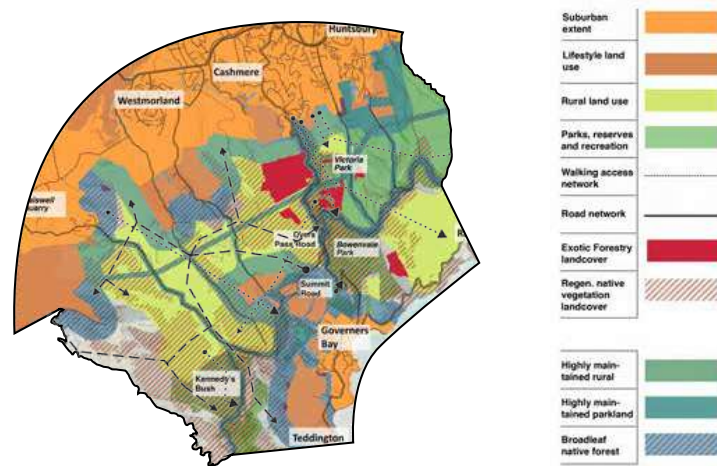


Figure 68 // Alternative futures with historic fires overlay including the 2017 Port Hills fires

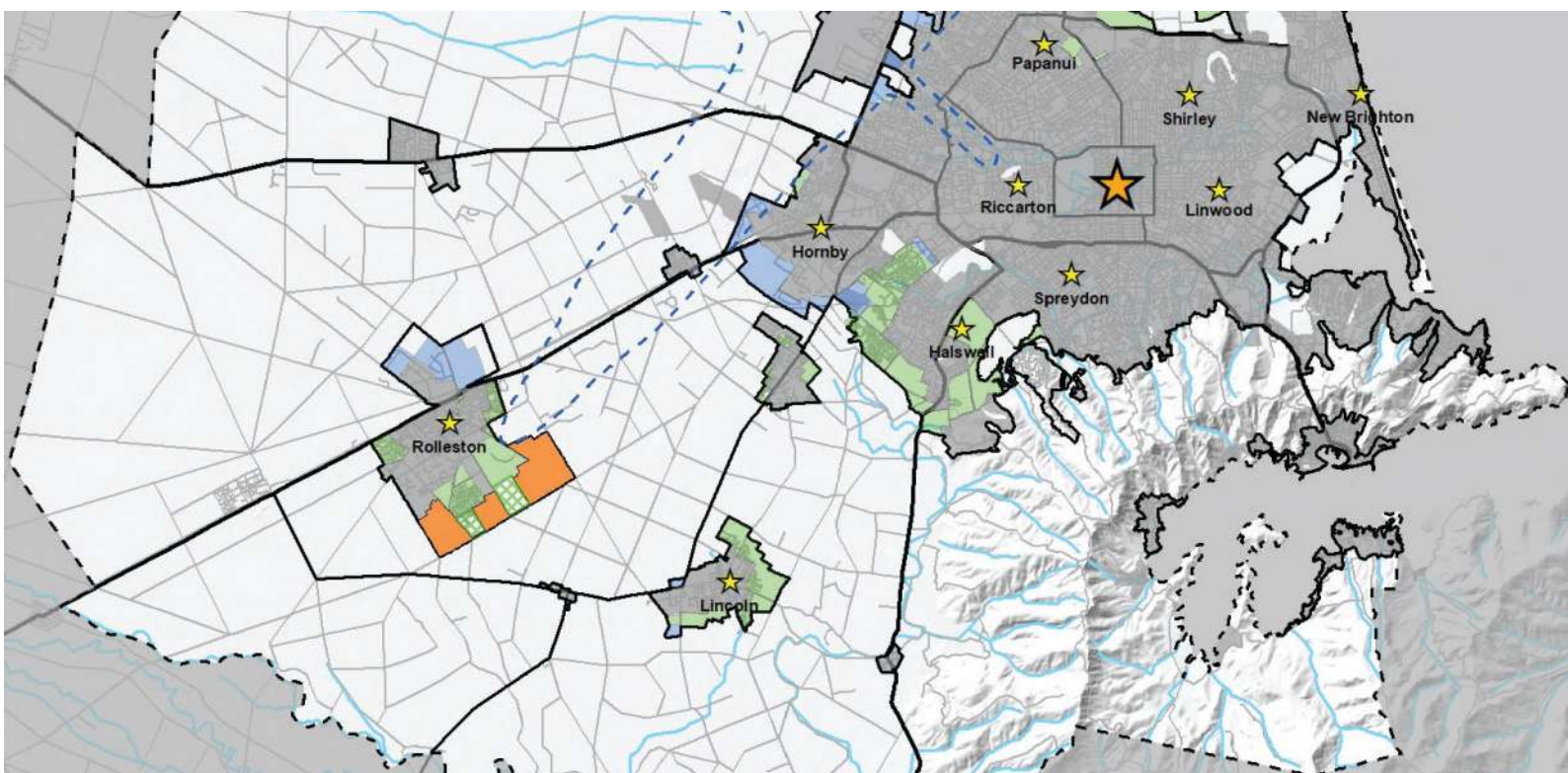


Figure 69 // The Greater Christchurch settlement pattern through to 2028 (Environment Canterbury, 2016)

Chapter 7 Conclusion: Key findings and implications

Key findings

This thesis responds to the question *‘What impact does spatial landscape change have upon wildfire threat in New Zealand peri-urban landscapes, and furthermore what is the potential and implications for spatial planning to manage this threat?’*.

In answering this question, the following objectives were identified with the first three already explored in the past chapter and can be summarised follows:

Objective A) Review literature to determine and evaluate the nature of peri-urban wildfire threat management, and compare New Zealand approaches with international approaches. The chapter three literature review finds that New Zealand is moving towards a more comprehensive and international model of peri-urban wildfire management, except for the usage of spatial planning. Spatial planning has been particularly underexplored by planners, specialists, and governing bodies in New Zealand, who also have a statutory obligation under the RMA 1991.

Objective B) Investigate the role and influences of past landscape change in a case-study example of the Port Hills (as an example of a New Zealand peri-urban landscape), evaluating how this has affected wildfire threat in the past and more recently with the 2017 Port Hills fires. Chapters four and five finds that despite a long history of wildfire threat related to landscape changes, the Port Hills 2017 Fires recovery has reflected New Zealand trends with a minimal use of spatial planning. Its only mention being a scheduled exploration of spatial planning options for Port Hills wildfire management set to take place after the recovery budget has been spent.

Objective C) Explore the capacity of spatial planning to manage this wildfire threat in the Port Hills, comparing this against continuing with current spatial planning directions. The chapter six alternative futures study shows that the current spatial planning trajectories for the Port Hills will likely retain and reinstate the pre-fire landscape and its embodied wildfire threat. Furthermore, it illustrates how spatial planning could be used to effectively manage the Port Hills wildfire threat at landscape scale, taking advantage of and managing landscape changes such as marginalisation of pastoral farmland and residential expansion. The chapter also highlights the missed spatial planning opportunity to capitalize on the policy window and extensive ‘blank-slate’ areas after the 2017 Port Hills Fires.

These key findings establish a basis for the final objective, which is to *‘assess the opportunities and implications for including wildfire management within peri-urban spatial planning practice in New Zealand’*. This is discussed below.

Opportunities and implications for including wildfire management within New Zealand peri-urban spatial planning practice

Spatial planning is an emerging practice in New Zealand, responding to disjointed and non-contextual planning, especially around urban peripheries (Boffa Miskell, 2016; Ministry for the Environment, 2010; Totman, 2015). Spatial planning differs from other planning approaches in that it specifically works to coherently bring together a wide array of land uses and systems, both cultural and biophysical (Ministry for the Environment, 2010). Furthermore, spatial planning does not prescribe regulation, rather it gives evidence and cross-boundary guidance to other more-detailed and secular planning documents which do prescribe regulation (Boffa Miskell, 2016; Ministry for the Environment, 2010). For example, the Canterbury Regional Policy Statement (CRPS) and the Greater Christchurch Urban Development Strategy (UDS) are spatial planning documents which guides development along the principles of the RMA to make Christchurch a liveable, safe sustainable and healthy place (Environment Canterbury, 2016). These documents then guide regulative planning in the Christchurch District Plan, for example the 2028 urban extents are closely reflected in the CDD zoning.

As a practice dealing with multi-value and long-term issues within applied landscapes, spatial planning is well suited to manage the context-dependent and multi-faceted nature of wildfire threat, yet this also means that wildfire will be balanced against other high-priority values. The changes necessary for wildfire management to play a role in spatial planning would require a significant valuing of ongoing wildfire threat, which with the example of the Port Hills fires and other more rural yet significant fire events throughout New Zealand, have incited only short-term awareness of wildfire threat (Hart & Langer, 2011). In countries such as Australia, wildfire events are more frequent so wildfire threat is a more long-term concern and can be a significant player within spatial planning (Syphard et al., 2013). Furthermore, the outcomes of the Alternative Futures show that wildfire management in the Port Hills would demand spatial and land management changes which conflict with significant economic and social values, with residential development, forestry, and succession method native revegetation, leading to resistance from governing bodies, institutions and public.

As spatial planning is an evidence-based planning process, further research could effectively prioritise wildfire management values. This approach could foreseeably leverage on the significant research body around wildfire management in New Zealand (particularly by SCION), using tools such

as Wildfire Threat Analysis to evaluate the effectiveness of spatial planning actions such as have been explored in this thesis. However, even with evidential backing, spatial planning would likely entail resistance from public. For example, the management of slope stability hazards on the Port Hills which was identified within the CRPS in 2011 and the UDS in 2013 as a response to the 2011 earthquakes, led to the retreat from several homes and regulated Slope Instability Management Areas in the Christchurch District Plan. This local governance reaction was well substantiated with evidence and reflects aspects of the proposed wildfire management actions in chapter 6, however the regulations and the processes by which they came about left effected residents 'enormously frustrated' with the "risk-averse" council, and looking to challenge this new 'status quo' (Coffey, 2014; Greenhill, 2013; Independent Hearing Panel - Christchurch Replacement District Plan, 2016). This supports a co-developed approach to spatial planning, which encourages identification and uptake by regulation affected communities (Dunn, Thompson, & Calkin, 2017).

Scenario three gives an insight into the capacity for managing wildfire threat in the Port Hills by exploring dramatic spatial changes stemming from wildfire management principles. However, it's important to note that the spatial planning needed in the Port Hills and throughout New Zealand will require a much more extensive process of collaboration, evidential proofing and temporal consideration. In this light, the purpose of this thesis is to clearly demonstrate the impact, need and potential for spatial planning to manage New Zealand peri-urban wildfire threat, and therefore the pressing need for further research, education, resource assignment, and development in the area. Spatial planning will otherwise continue to perpetuate peri-urban wildfire events throughout New Zealand, without any accountability for being able to manage this same issue.

Bibliography

- AFAC. (2017). *Independent Operational Review*. Retrieved from <https://fireandemergency.nz/assets/Documents/Files/AFAC-Port-Hills-Review.pdf>
- Agar, J. (2015). Summit Road could realise as-yet unfulfilled potential. *The Press*.
- Bardsley, D., Weber, D., Robinson, G., Moskwa, E., & Bardsley, A. (2015). Wildfire risk, biodiversity and peri-urban planning in the Mt Lofty Ranges, South Australia. *Applied Geography*, 63, 155-165.
- Bellard, S., Benson, T., Carter, R., Corballis, T., Joyce, Z., Moore, H., . . . Smith, V. (2015). *A Transitional Imaginary: Space, Network and Memory in Christchurch*. Christchurch: Harvest.
- Bhandary, U., & Muller, B. (2009). Land use planning and wildfire risk mitigation: an analysis of wildfire-burned subdivisions using high resolution remote sensing imagery and GIS data. *Journal of Environmental Planning and Management*, 52(7), 939-955.
- Bihari, M., Hamin, H., & Ryan, R. (2012). Understanding the Role of Planners in Wildfire Preparedness and Mitigation. *ISRN Forestry*, 1-12.
- Boffa Miskell. (1985). Port Hills Landscape Study Volume 1: Study Summary.
- Boffa Miskell. (2007). *Banks Peninsula Landscape Study*. Retrieved from <http://resources.ccc.govt.nz/files/policiesreportsstrategies/chapter9-naturalandculturalheritage-s32-appendix3.4-bankspeninsulalandscapestudy2007.pdf>
- Boffa Miskell. (2015). *Ōtautahi/ Christchurch City Landscape Study*. Retrieved from Christchurch: <http://resources.ccc.govt.nz/files/thecouncil/meetingsminutes/agendas/2015/april/chapter9naturalandculturalheritagesection32appendix33landscapecharacterdescriptionschristchurchcitylandscapestudy.pdf>
- Boffa Miskell. (2016). *Spatial Planning Opportunities and Options for Metropolitan Wellington; Prepared for the Local Government Commission*. Retrieved from Wellington: <http://www.lgc.govt.nz/assets/Wellington-Spatial-Planning/Wellington-Region-Spatial-Plan-Report-May-2016.pdf>
- Bones, H. (2005). *Wildfires and Communities: International Perspectives*. Retrieved from Christchurch: <https://fgr.nz/documents/download/1193>
- Bowman, D. M. J. S., Balch, J., Artaxo, P., Bond, W. J., Cochrane, M. A., D'Antonio, C. M., . . . Swetnam, T. W. (2011). The human dimension of fire regimes on Earth. *Journal of Biogeography*, 38(12), 2223–2236.
- Bridge, J. (2010). Mitigating Wildfire Disaster: Early Detection and Commitment. *Disaster Recovery Journal*, 1629.
- Burby, R., Deyle, R., Godschalk, D., & Olshansky, R. (2000). Creating Hazard resilient Communities through Land-Use Planning. *Natural Hazards Review*, 1(2).
- Burry, M. (2018). Natives struggle to regenerate on Port Hills. *Radio New Zealand*. Retrieved from <https://www.radionz.co.nz/news/national/349832/natives-struggle-to-regenerate-on-port-hills>
- Butsic, V., Syphard, A. D., Keeley, J. E., & Bar-Massada, A. (2017). Can private land conservation reduce wildfire risk to homes? A case study in San Diego County, California, USA. 157, 161–169.
- Buxton, M., Haynes, R., Mercer, D., & Butt, R. (2011). Vulnerability to Bushfire Risk at Melbourne's Urban Fringe: The Failure of Regulatory Land Use Planning. *Geographical Research*, 49(1), 1-12.

- Cairns, L. (2015). Council urged to keep Summit Rd closed to cars. *The Press*, May 15 2015.
- Calkin, D., Cohen, J., Finney, M., & Thompson, M. (2013). How risk management can prevent future wildfire disasters in the wildland-urban interface. *Environmental Sciences*, 111(2), 746-751.
- Carswell, F. (2017, 13/03/2017). Port Hills fires: Lessons for the entire country. *Stuff NZ*.
- Cashmere Estate Ltd. (2017). Artists Impression. Retrieved from <https://www.facebook.com/cashmereestate/>
- Champ, J., Brooks, J., & Williams, D. (2012). Stakeholder Understandings of Wildfire Mitigation: A Case of Shared and Contested Meanings. *Environmental Management*, 50, 581–597.
- Christchurch Adventure park. (2016). About the Christchurch Adventurepark. Retrieved from <https://www.christchurchadventurepark.com/>
- Christchurch City Council. (1991). *Cashmere Spur and Bowenvale Valley Reserves Management Plan*. Retrieved from Christchurch,: <https://www.ccc.govt.nz/assets/Documents/The-Council/Plans-Strategies-Policies-Bylaws/Plans/Park-management-plans/CashmereSpurBowenvaleValley-ManagementPlan-ocr.pdf>
- Christchurch City Council. (2003). *Waterways, wetlands and drainage guide*. Retrieved from Christchurch: <https://www.ccc.govt.nz/environment/water/water-policy-and-strategy/waterways-wetlands-and-drainage-guide>
- Christchurch City Council. (2008a). *Biodiversity Strategy 2008*. Retrieved from Christchurch: <https://www.ccc.govt.nz/the-council/plans-strategies-policies-and-bylaws/strategies/biodiversity-strategy-2008/>
- Christchurch city Council. (2008b). *Christchurch City Council Biodiversity Strategy*. Retrieved from
- Christchurch City Council. (2010). Fact Sheet; Port Hills.
- Christchurch City Council. (2014a). *Decision of The Christchurch City Council on Resource Consent Application RMA92026094*. Retrieved from Christchurch: <http://resources.ccc.govt.nz/files/haveyoursay/RMA92026094Decisionincludingconditions.pdf>
- Christchurch City Council. (2014b). *Rural Fire Management; Activity Management Plan*. Retrieved from Christchurch: <https://ccc.govt.nz/assets/Documents/The-Council/Plans-Strategies-Policies-Bylaws/Plans/Long-Term-Plan/typ2013/ACMP-TYP2013-16-RuralFireManagement.pdf>
- Christchurch City Council. (2016). *Christchurch District Plan*. Retrieved from Christchurch: <https://www.ccc.govt.nz/the-council/plans-strategies-policies-and-bylaws/plans/christchurch-district-plan>
- Christchurch City Council. (2017a). Drones used in NZ-first trial to reseed Port Hills [Press release]. Retrieved from <https://ccc.govt.nz/news-and-events/newsline/show/1496>
- Christchurch City Council. (2017b). *Port Hills Fire Recovery Plan Discussion Document*. Christchurch: Christchurch City Council.
- Christchurch City Council. (2017c). *Port Hills Fires Recovery Plan*. Christchurch: Christchurch City Council,.
- Christchurch City Council. (2017d). Where our water comes from. Retrieved from <https://cccgovtnz.cwp.govt.nz/services/water-and-drainage/water-supply/about-the-water-supply/where-our-water-comes-from/>

- Christchurch City Council. (2018a). *Capital Programme Overview*. Retrieved from Christchurch: <https://www.ccc.govt.nz/assets/Documents/The-Council/Plans-Strategies-Policies-Bylaws/Plans/Long-Term-Plan/draft2018/Capital-Programme-Schedules-2.pdf>
- Christchurch City Council. (2018b). Summit Road Proposed prohibited times on road restrictions. Retrieved from <https://www.ccc.govt.nz/the-council/consultations-and-submissions/haveyoursay/show/56>
- Coffey. (2014). *Has your Port Hills property been zoned correctly?* Retrieved from Christchurch: <https://www.coffey.com/assets/Ingenuity/Insight-has-your-Port-Hills-property-been-zoned-correctly.pdf>
- Cohen, J. (2008). The Wildland-Urban Interface Fire Problem: A Consequence of The Fire Exclusion Paradigm. *Fremontia*, 38(2-3), 16-22.
- Corry, R., & Nassauer, J. (2004). Using normative scenarios in landscape ecology. *Landscape Ecology*, 19, 343–356.
- Council, C. C. (2009). *South-West Christchurch Area Plan* Christchurch City Council Retrieved from <https://www.ccc.govt.nz/assets/Documents/The-Council/Plans-Strategies-Policies-Bylaws/Plans/area-plans/south-west/SWAP2009FinalDocumentLR-southwest.pdf>.
- Curran, T., Perry, G., Wyse, S., & Alam, M. (2018). Managing Fire and Biodiversity in the Wildland-Urban Interface: A Role for Green Firebreaks. *Fire*, 1(1), 3.
- Deming, M. E., & Swaffield, S. (2011). *Landscape Architectural Research: Inquiry, Strategy, Design*: John Wiley & Sons.
- Doherty, J. J., Anderson, S. A. J., & Pearce, G. (2008). *An analysis of wildfire records in New Zealand: 1991-2007*. Retrieved from https://www.researchgate.net/publication/299199294_An_analysis_of_wildfire_records_in_New_Zealand_1991-2007
- Dunn, C., Thompson, M., & Calkin, D. (2017). A framework for developing safe and effective large-fire response in a new fire management paradigm. *Forest Ecology and Management*, 404(15), 184-196.
- Dwyer, C. (2014). *The Stories of Banks Peninsula: Connecting Maori Oral Traditions, European History, and Geological and Ecological Perspectives*. University of Canterbury.
- Edgeley, C., & Paveglio, T. (2016). Influences on stakeholder support for a wildfire early warning system in a UK protected area. *Environmental Hazards*, 15(4), 327-342.
- Environment Canterbury. (2016). *Greater Christchurch Urban Development Strategy Update*. Retrieved from Christchurch: <http://greaterchristchurch.org.nz/assets/Uploads/5243-PLAN-Urban-Development-Strategy-Update-Aug2016-SCREEN-Final.pdf>
- Environment Canterbury. (2017). *Canterbury Regional Policy Statement 2013*. Retrieved from Christchurch: <https://www.ecan.govt.nz/your-region/plans-strategies-and-bylaws/canterbury-regional-policy-statement/>
- FENZ. (2017a). *Engaging Owners of Lifestyle Blocks in Understanding and Mitigating Wildfire Risks*. Retrieved from <https://fireandemergency.nz/assets/Documents/Files/lifestyle-block-owners-report-157-Dec-2017.pdf>
- FENZ. (2017b). *Fire and Emergency New Zealand Blueprint 2017-2020*. Retrieved from <https://fireandemergency.nz/assets/Documents/About-FENZ/Key-documents/FENZ-Blueprint-2017-20-Final-v2017-11-30.pdf>
- FENZ. (2017c). *Port Hills Fires - 2017 Operational Action Plan*. Retrieved from Wellington: <https://fireandemergency.nz/assets/Documents/Files/Action-Plan-Summary.pdf>
- Fernandes, P., & Botelho, H. S. (2003). A review of prescribed burning effectiveness in fire hazard reduction. *International Journal of Wildland Fire*, 12(12), 117-128.

- Fire and Emergency New Zealand. (2017). The FENZ Transition Project. Retrieved from <http://fenzproject.co.nz/>
- Fletcher, J. (2018). Status Green: Native tree fundraiser at Christchurch Adventure Park. *The Press*.
- Fogarty, L. (2002). *Flammability guide for some common New Zealand native tree and shrub species*. Retrieved from Wellington: <https://fireandemergency.nz/assets/Documents/Research-and-reports/Report-20-A-Flammability-Guide-for-Some-Common-New-Zealand-Native-Tree-and-Shrub-Species.PDF>
- Furlaud, J., Williamson, G., & Bowman, D. (2018). Simulating the effectiveness of prescribed burning at altering wildfire behaviour in Tasmania, Australia. *International Journal of Wildland Fire*, 27, 15–28.
- Gardner-Hopkins, J., & Fairgray, D. (2011). *Spatial Planning: Evidence and Evaluation*. Paper presented at the New Zealand Planning Institute Conference, Wellington.
- Gill, A. M. (2005). Landscape fires as social disasters: An overview of 'the bushfire problem'. *Environmental Hazards*, 6(2), 65-80.
- Gill, A. M., Stephens, S., & Cary, G. (2013). The worldwide “wildfire” problem. *Ecological Applications*, 23(2), 438–454.
- Godber, A. (1915-1949). Gates of Victoria Park: National Library.
- Graham, R., McCaffrey, S., & Jain, T. (2004). *Science Basis for Changing Forest Structure to Modify Wild re Behavior and Severity*. Retrieved from <https://www.fs.usda.gov/treearch/pubs/6279>
- Greenhill, M. (2013). Port Hills red stickers to stay - mayor. *The Press*.
- Gucinski, H. (2001). *Forest Roads: A Synthesis of Scientific Information*: DIANE Publishing.
- Guild, D., & Dudfield, M. (2009). A history of fire in the forest and rural landscape in New Zealand *Journal of Forestry*, 59, 34-38.
- Hampton, S., & Cole, J. (2009). Lyttelton Volcano, Banks Peninsula, New Zealand: Primary volcanic landforms and eruptive centre identification. *Geomorphology*, 104, 284–298.
- Harris, L., McGee, T. K., & McFarlane, B. (2011). Implementation of wildfire risk management by local governments in Alberta, Canada. *Journal of Environmental Planning and Management*, 54(4), 457-475.
- Hart, M., & Langer, L. (2011). Mitigating the risk of human caused wildfires: literature review and stakeholder study. (Scion Contract Report No. 18090), 57.
- Hayward, M. (2018). High Court action over liability for Port Hills fires continues. *The Press*. Retrieved from <https://www.stuff.co.nz/the-press/news/101057127/high-court-action-over-liability-for-port-hills-fires-continues>
- Hewgill, G. (2009). Christchurch from the Port Hills *Flickr*.
- Hogan, D. (2014). *District Plan review, Rural Chapter 17 Section 32: Appendix 5*. Retrieved from http://resources.ccc.govt.nz/files/TheCouncil/policiesreportsstrategies/districtplanning/districtplanreview/dpr_rural_section32_appendix5_backgroundreport_rural.PDF
- Hogan, D. (2014). *The rural environment of Christchurch District*.
- Hogans, M. (1979). *A 3-year pattern of dispersed recreation and forest fires in Pacific Northwest forests*. Portland, Oregon: Dept. of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.
- Houtman, R., Montgomery, C., Gagnon, A., Calkin, D., Dietterich, T., McGregor, S., & Crowley, M. (2013). Allowing a wildfire to burn: estimating the effect on future fire suppression costs. *International Journal of Wildland Fire*, 22, 871–882.

- Hoversten, M. (2014). *Decision-making, Values, and Discursive Moments in Alternative Futures Landscape Planning*. Lincoln University, Christchurch.
- Independent Hearing Panel - Christchurch Replacement District Plan. (2016). *Stage 1 Rehearing of Certification for Cliff Collapse Management Areas*. Retrieved from Christchurch: <http://www.chchplan.ihp.govt.nz/wp-content/uploads/2015/03/Decision-15-Natural-Hazards-Part-Stage-1-Rehearing-of-Certification-for-Cliff-Collapse-Management-Areas-3-3-2016-.pdf>
- Jack, J. (2017). *Port Hill fire-damaged soil GIS Maps*.
- Jakes, P. J., Kelly, L., & Langer, L. (2010). An exploration of a fire-affected community undergoing change in New Zealand. *The Australian Journal of Emergency Management*, 25(3), 48-53.
- Jakes, P. J., & Langer, L. (2012). The adaptive capacity of New Zealand communities to wildfire. *International Journal of Wildland Fire*, 21(6), 764-772.
- Johnstone, J., Allen, C., Franklin, J., Frelich, L., Harvey, B., Higuera, P., . . . Schoennagel, T. (2016). Explaining fire-driven landscape transformation during the Initial Burning Period of New Zealand's prehistory. *Frontiers in Ecology and the Environment*, 14(7), 369-378.
- Kelly, L. (2005). *Wildfires and Communities: Australasian Perspectives*. Retrieved from Christchurch: <https://fgr.nz/documents/download/1215>
- Kennelly, A. G. (1949). Intensive small farming in the Port Hills : early and late produce for Christchurch market. *New Zealand Journal of Agriculture*.
- Kirk-Anderson, J. (2016). Fireworks said to have caused large fire on Christchurch's Port Hills. *Stuff.co.nz*.
- Klein, E. (2017). *Community wildfire planning and design: a review and evaluation of current policies and practices in the western united states*. (Masters of Landscape Architecture), Utah State University, Logan, Utah.
- Kocher, S., & Butsic, V. (2017). Governance of Land Use Planning to Reduce Fire Risk to Homes Mediterranean France and California. *Land*, 6, 24.
- Koebele, E., D., C., L., D., Schild, R., Kroepsch, A., & Clifford, K. (2014). *Risk Perceptions, Management Regimes, and Wildfire Mitigation Behavior in Wildland-Urban Interface Zones: A Cross-Case Analysis*. Paper presented at the Western Political Science Association Annual Conference, Seattle, WA.
- Langer, L. (2018). *Port Hills Fire Overview for Special Issue of Disaster and Trauma Studies on the Canterbury Fires in 2017*. Incident Summary for Special Issue. SCION,. Christchurch.
- Langer, L., & McGee, T. K. (2017). Wildfire risk awareness and prevention by predominantly Māori rural residents, Karikari Peninsula, Aotearoa New Zealand. *International Journal of Wildland Fire*, 26(9), 820-828.
- Law, T. (2016). 380-home Cashmere subdivision gets green light. *The Press*.
- Leask, J. (2017, 19/02/2017). Port Hills fire under control but not out yet. *Stuff NZ*.
- LUCAS NZ (Cartographer). (2017). Land use maps. Retrieved from <https://data.mfe.govt.nz/layer/52375-lucas-nz-land-use-map-1990-2008-2012-v018/>
- Majorhazi, K., & Hansford, A. (2011). New Zealand Wildfire Threat Analysis; workbook documentation for national rural fire authority.
- McCaffrey, S., Toman, E., Stidham, M., & Shindler, B. (2012). Social science research related to wildfire management: an overview of recent findings and future research needs. *International Journal of Wildland Fire*, 22(1), 15-24.

- McNamara. (2017) *The new age of fire: Why infernos like Port Hills could become more common*/Interviewer: R. Macfie. Noted.co.nz, Christchurch.
- Miller, C., & Ager, A. (2013). A review of recent advances in risk analysis for wildfire management. *International Journal of Wildland Fire*, 22, 1-14.
- Ministry for Culture and Heritage. (2012). 'Pressure groups'. *Scenery preservation 1903-1953*. Retrieved from <https://nzhistory.govt.nz/culture/scenery-preservation/pressure-groups>
- Ministry for the Environment. (2010). *Building competitive cities, Reform of the urban and infrastructure planning system. A discussion document*. Retrieved from Wellington:
- Ministry for the Environment. (2015). *Getting in on the Act; An everyday guide to the RMA*. Retrieved from Wellington:
- Moritz, M. A., Batllori, E., Bradstock, A., Gill, A. M., Handmer, J., Hessburg, P., . . . Syphard, A. (2014). Learning to coexist with Wildfire. *Nature*, 515, 58–66.
- Muerk, C. (2017). A Vegetation Recovery Scenario with Required Actions for the Port Hills (Meeting Summary) [Press release]
- National Wildfire Coordinating Group. (2015). *Glossary of Wildland Fire Terminology*. Retrieved from <https://www.nwccg.gov/glossary-of-wildland-fire-terminology>
- New Zealand Government. (1991). *The Resource Management Act*. Retrieved from New Zealand: www.mfe.govt.nz/rma
- Nightingale, T., & Dingwall, P. (2003). *Our Picturesque History; 100 Years of scenery preservation in New Zealand*. Wellington: Department of Conservation.
- Norman, B., Weir, J., Sullivan, K., & Lavis, J. (2014). *Planning and Bushfire Risk in a changing climate*. Retrieved from Australia: http://www.bushfirecrc.com/sites/default/files/urban_and_regional_planning.pdf
- Norman, E. (Cartographer). (1855). Canterbury Plains,- New Zealand. Retrieved from <http://mp.natlib.govt.nz/detail/?id=8818&l=en>
- Northcott, M. H., M. (2017, 10/03/2017). Damage assessment, rebuild plans begin at Christchurch Adventure Park after Port Hills fire. *The Press*.
- Ogilvie, G. (1978). *The Port Hills of Christchurch*. Wellington: AH and AW Reed.
- Ogilvie, G. (2000). *Enjoying the Port Hills*: Summit Road Society.
- Orwin, J. (2008). *Port Hills - protect and enjoy; A guide to restoration and recreation on the hills above Christchurch*: Summit Road Society,.
- Parliamentary Commissioner for the Environment. (2001). *Managing Change in Paradise: Sustainable Development in Peri-urban Areas*. Retrieved from Wellington:
- Paveglio, T., Carroll, M. S., & Jakes, P. J. (2008). Alternatives to evacuation—protecting public safety during wildland fire. *Journal of Forestry*, 106(2), 65-70.
- Paveglio, T., Carroll, M. S., & Jakes, P. J. (2010). Alternatives to evacuation during wildland fire: Exploring adaptive capacity in one Idaho community. *Environmental Hazards*, 9(4), 379-394.
- Paveglio, T., & Edgeley, C. (2017). Community diversity and hazard events: understanding the evolution of local approaches to wildfire. *Natural Hazards*, 87(2), 1083–1108.
- Paveglio, T. B., Nielsen-Pincus, M. W., Abrams, J. B., & Moseley, C. (2017). Advanced characterization of social diversity in the wildland-urban interface: An indicator approach for wildfire management. 160, 115-126.
- Pearce, G. (2017). Previous Port Hill Fires *Excel Spreadsheet*. Christchurch: SCION,.

- Pearce, G., & Alexander, M. E. (1994). Fire Danger Ratings Associated with New Zealand's Major Pine Plantation Wildfires. *Proceedings of the 12th International Conference on Fire and Forest Meteorology*, 534-543.
- Pearce, G., & Anderson, A. (2008). The role of research in managing forest and rural fire risk. *NZ JOURNAL OF FORESTRY*, 53(3).
- Pearce, G., & Langer, L. (2017). Improving community resilience to wildfire. Retrieved from <https://www.scionresearch.com/about-us/about-scion/corporate-publications/scion-connections/past-issues-list/issue-15,-march-2015/improving-community-resilience-to-wildfire>
- Pearce, G., Langer, L., Harrison, R. R., & Hart, M. (2014). *Describing Wildfire Prone Areas in the New Zealand Context: Final Report*. Retrieved from <https://fireandemergency.nz/assets/Documents/Research-and-reports/Report-134-Wildfire-Prone-Areas.pdf>
- Pearce, G., Teeling, A., & Clifford, V. (2013). Fire Risk Management Treatment Guideline Christchurch Port Hills.
- Pearce, H. G., Mullan, A. B., Salinger, M. J., Opperman, T. W., Woods, D., & Moore, J. R. (2005). Impact of Climate Change on Long-term Fire Danger. *New Zealand Fire Service Commission Research Report No. 50*.
- Penman, T., Erikson, C., Horsey, B., Green, A., Lemcke, D., Cooper, P., & Bradstock, R. (2017). Retrofitting for wildfire resilience: What is the cost? *International Journal of Disaster Risk Reduction*, 21, 1-10.
- Petrovic, N., Alderson, D., & Carlson, J. (2012). Dynamic Resource Allocation in Disaster Response: Tradeoffs in Wildfire Suppression. *PLoS ONE*, 7(4).
- Purey-Cust, J. (2001). Privatisation of State forest plantations - did we do it right? *The New Zealand Journal of Forestry*, 45(4).
- Rasker, R., & Barrett, K. (2016). *Land Use Planning to Reduce Wildfire Risk: Lessons from Five Western Cities*. Retrieved from Bozeman:
- Rastandeh, A. (2015). Challenges and potentials in using alternative landscape futures during climate change: A literature review and survey study. *Urbani izziv*, 26(2), 83–102.
- Rob Greenaway & Associates. (2004). *Port Hills Recreation Strategy*. Retrieved from
- Robertson, J. (2016). *Head of the Harbour*. Governors Bay: Philip King Publisher.
- Rooney, D. (1993). Forest Fire Bills Alarm. *The Press*.
- Rundel, P., & King, P. (2001). Ecosystem processes and dynamics in the urban/wildland interface of Southern California. *Journal of Mediterranean Ecology*, 2, 209 - 219.
- Rutherford, B. (2017). Authorities meet about water supply after Port Hills fire. *Star.kiwi*, November the 20th.
- Schwab, J., Meck, S., & Simone, J. (2005). *Planning for Wildfires*. Retrieved from USA:
- SCION. (2015). Improving community resilience to wildfire. *Scion connections*(15), 4-5.
- SCION. (2017). *ISSUE: South Island, February 2018*. Retrieved from Christchurch: <https://fireandemergency.nz/assets/Documents/Seasonal-Fire-Danger-Outlook/South-Island-Seasonal-Fire-Danger-Outlook-February-2018.pdf>
- Selwyn District Council. (2010). *Council Report on Port Hills for Plan Change 6 Lower Port Hills*.
- Selwyn District Council. (2016). *The operative Selwyn district plan 2016*.
- Smith, A., Kolden, C. A., Paveglio, T. B., Cochrane, M. A., Bowman, D. M. J. S., Moritz, M. A., . . . Abatzoglou, J. T. (2016). The Science of Firescapes: Achieving Fire-Resilient Communities. *Bioscience Journal*, 66(2), 130-146.

- Smith, R. (2009). *Firebreak Location, Construction and Maintenance Guidelines*. Retrieved from
- Stahlschmidt, P. (2017). *Landscape Analysis: Investigating the potentials of space and place*. Routledge.
- Stapylton-Smith, M. (2009). *Adderley to Bradley; A history of the southern bays of Lyttelton Harbour*. Friends of Diamond Harbour Library.
- Strand, T. (2017, 16/02/2017). Port Hills: Your questions answered. *Radio New Zealand*.
- Sturtevant, V., & Jakes, P. J. (2010). Collaborative planning to reduce risk. In W. Martin, C. Raish, & B. Kent (Eds.), *Wildfire Risk: Human Perceptions and Management Implications*. Routledge.
- Summit Road Society. (2001). Editorial. *Summit Road Society Newsletter, November 2001*.
- Summit Road Society. (2003). Resource Management Activities. *Summit Road Society Newsletter, May 2003*.
- Summit Road Society. (2017a). About the Summit Road Society. Retrieved from http://www.summitroadsociety.org.nz/?page_id=276
- Summit Road Society. (2017b). History of Harry Ell & The Summit Road. Retrieved from http://www.summitroadsociety.org.nz/?page_id=24
- Summit Road Society. (2017c). *Job Description: Executive Secretary*. Retrieved from Christchurch: <https://www.summitroadsociety.org.nz/wordpress/wp-content/uploads/2017/09/Executive-Secretary-job-description-September-2017.pdf>
- Summit Road Society. (2017d). Ohinetahi Bush Reserve. *Summit Road Society*.
- Swaffield, S., Primdahl, J., & Hoversten, M. (2013). Discursive Relationships Between Landscape Science, Policy and Management Practice: Concepts, Issues and Examples. In B. Fu, Jones, Bruce K. (Ed.), *Landscape Ecology for Sustainable Environment and Culture* (pp. 225-248): Springer Netherlands.
- Swager, J. D. (2004). *Managing Water Resources for Fighting Wildland- Urban/Interface Fires in New Zealand: A GIS-based approach to better management in the Port Hills of Christchurch*. Lincoln University, Lincoln.
- Syphard, A., Massada, A., Butsic, V., & Keeley, J. E. (2013). Land Use Planning and Wildfire: Development Policies Influence Future Probability of Housing Loss.
- T. P. D. (1920). The view of Christchurch taken from a section of the Cashmere Hills that is about to be developed. Christchurch City Libraries.
- Taylor, M., & Freeman, S. (2010). *A review of planning and operational models used for emergency evacuation situations in Australia*. Paper presented at the First International Conference on Evacuation Modeling and Management.
- Taylor, S. (2017). Forage: Gorse loses battle with Italian ryegrass. *NZ Farm Life Media*.
- The Banks Peninsula Conservation Trust. (2018). About Us. Retrieved from <http://www.bpct.org.nz/about-us/us>
- The New Zealand Fire Service Commission. (2015). *Funding Fire and Emergency Services for all New Zealanders*. Retrieved from http://www.firelevy.co.nz/Resources/Fire_Levy_Consultation_Document.pdf
- The Press. (1889). Bush and Grass Fires. *The Press*.
- The Press. (1897). Serious Grass Fire. *The Press*.
- The Press. (1908). Cashmere Hills Fire. *The Press*.
- The Press. (1931). Kennedys Bush Burnt Out. *The Press*.
- The Press. (1935a). Beating Back a Fire. *The Press*.
- The Press. (1935b). Gorse Fire On Cashmere Hills. *The Press*.
- The Press. (1988). Firemen battle hillside blaze. *The Press*.

- The Rod Donald Trust. (2016). *Statement of Intent*. Retrieved from Banks Peninsula: <http://roddonaldtrust.co.nz/wp-content/uploads/2017/02/RDBPT-Statement-of-Intent-Year-ending-June-2017.pdf>
- Toman, E., Shindler, B., & Brunson, M. (2006). Fire and fuel management communication strategies: citizen evaluations of agency outreach activities. *Society & Natural Resources*, 19(4), 321-336.
- Totman, D. (2015). Waipa District Council Submission; Better urban planning [Press release]. Retrieved from <https://www.productivity.govt.nz/sites/default/files/sub-urban-planning-02-waikato-district-council-2245Kb.pdf>
- UNISDR. (2017). 6. *Wildfire Hazard and Risk Assessment*. Retrieved from https://www.unisdr.org/files/52828_06wildfirehazardandriskassessment.pdf
- Unknown. (1910). Roadmen building the Summit Road the view looking towards Kennedy Bush. Christchurch: Christchurch City Libraries.
- unknown. (1920). Cooper's Knob from Kennedy's Bush [picture]. In H. E. papers (Ed.): Christchurch City Libraries,.
- Vallance, F. (2017). The Port Hills fire on day three *Wikipedia commons*.
- Wikipedia commons. (2012). Christchurch south view. In https://commons.wikimedia.org/wiki/File:Christchurch_south_view.jpg (Ed.), *Wikipedia*.
- Williams, E. (2009). Māori Fire Use and Landscape Changes in Southern New Zealand. *Journal of the Polynesian Society*, 118, 175-189.
- Wilson, H. (2013). *Plant life on Banks Peninsula*: Manuka Press.
- Woodford, K. (2017). Keith Woodford examines lessons of Port Hills fire. *NZ Farmer*.
- Wooten, G. (2003). *Fire and fuels management: Fire and fuels management: Definitions, ambiguous terminology and references*. Retrieved from Twisp, Washington: <https://www.nps.gov/olym/learn/management/upload/fire-wildfire-definitions-2.pdf>
- Wyse, S., Perry, G., & Curran, T. (2017). Shoot-Level Flammability of Species Mixtures is Driven by the Most Flammable Species: Implications for Vegetation-Fire Feedbacks Favouring Invasive Species. *Ecosystems*.

Appendices

Appendix A - Expanded alternative future and landscape change trajectory comparison chart with mapping actions and source

	Alternative Future A Statutory Planning	Alternative Future B Scenic Preservation	Alternative Future C Peri-urban Wildfire Managed
Suburban residential	Leapfrog expansion on lower flanks, especially on spurs and south of Dyers Pass Road	Retreat and contain development to lower flanks	Consolidate low-flank belt and buffer
	<ul style="list-style-type: none"> - Depicted by all 'current urban extent' areas of the 2014 CCC landuse map (D. Hogan, 2014) - Depicted by all 2041 UDS Urban extents (Environment Canterbury, 2016) 	<ul style="list-style-type: none"> - Depicted as 2014 CCC landuse map which shows current urban extent, which on the Port Hills is assumed as all suburban (D. Hogan, 2014) - Shown as 2041 UDS Urban extent, however this is largely overlapped by 'suburban expansion' (a priority for Scenic Preservation.) (Environment Canterbury, 2016)) - No expansion shown above the 160m contour (LINZ, 2017) 	<ul style="list-style-type: none"> - Depicted by all 'current urban extent' areas of the 2014 CCC landuse map (D. Hogan, 2014). - Depicted by all 2041 UDS Urban extents (Environment Canterbury, 2016), avoiding any areas, excluding any areas within the extent of the 2017 fires (Jack, 2017), specifically effecting Westmorland spur. - Author alteration of UDS expansion patterns to follow a more consolidative trajectory by depicting suburban expansion on valley walls as well as spurs, to consolidate the urban boundary and avoid the affect of urban spurs framed by steep, hazardously vegetated valley walls. Specifically affecting the valley walls around Westmorland and Cashmere Spurs, and the retreat from the Redmund Spur subdivision. - Buffered with a 500m low-lying fuels and high-management zone.
Lifestyle residential	Leapfrog expansion on lower flanks, especially on spurs and south of Dyers Pass Road	Controlled expansion on lower flanks	Retreat and buffer
	<ul style="list-style-type: none"> - Lifestyle shown in all CCDP 'Large-lot residential' and 'Rural Urban Fringe' zones, which provision for lifestyle expansion (Christchurch City Council, 2016). However, these areas are largely overlapped by UDS urban boundary, in which case it is shown as subdivision (assuming economic weighting towards higher densification). - Lifestyle shown as 2014 Lifestyle landcover according to 2014 CCC landuse map (D. Hogan, 2014) 	<ul style="list-style-type: none"> - Depicted as CCDP 'Large-lot residential' and 'Rural Urban Fringe' zones depict provision for lifestyle expansion (Christchurch City Council, 2016). - Depicted as 2014 Lifestyle and 160m contour shown (LINZ, 2017; Hogan, 2014) - Hillside development of Cashmere Estate shown as lifestyle instead of suburban expansion. 	<ul style="list-style-type: none"> - Retreat from properties affected (properties with a damaged or destroyed house or those without a house where 50% or more of the property was burnt by the 2017 Port Hills Fire), specifically affecting the Westmorland and Halswell Spurs. - Deprecated without expansion provision areas under CCDP 'Large-lot residential' and 'Rural Urban Fringe' zones, specifically affecting the lower flanks of Westmorland where these areas are envisioned as suburban residential. - Buffered with a 500m low-lying fuels and high-management zone.

Roading and utility networks	Protect scenic access, expand to cater for residential demand, and control Summit Road access	Protection of scenic access along and up to ridges, yet controlled	Expanded patchwork of firebreaks/access, with controlled public access
	<ul style="list-style-type: none"> - <i>Roading depicted through the current ONRC (One Network Road Classification) hierarchy</i> - <i>Includes roading expansion shown in the 2012 Christchurch City Council Transportation Plan, and its Long-term Vision plan, e.g. Worsley Road and Huntsbury Avenue.</i> - <i>Imagined road expansion is also shown within urban expansion areas.</i> - <i>Shows NZ Powerline Centrelines (LINZ, 2011)</i> 	<ul style="list-style-type: none"> - <i>Roading depicted through the current ONRC (One Network Road Classification) hierarchy.</i> - <i>Controls of Summit Road assumed but not depicted.</i> 	<ul style="list-style-type: none"> - <i>Expanded vehicular network along non-connected roads of e.g. Worsley Road, Kennedy's Bush Road and Huntsbury Avenue, restricted from Public access yet can provide emergency service access and public emergency egress, and built as fire breaks with 15m buffer.</i> - <i>Create firebreak provisions along all roads across the Port Hills, specifically Dyers Pass Road and the Summit Road (utilising the Summit Road Protection Act jurisdiction).</i> - <i>Controls of Summit Road assumed but not depicted.</i>
Recreation and public access networks	Maintain and diversify	Maintain and expand along and up to the Scenic ridges, yet controlled	Sustained recreational public access, focus on short upper ridge routes
	<ul style="list-style-type: none"> - <i>Depicted through current track network as depicted through NZ Track Centrelines (LINZ, 2018) , with the additional Adventure Park tracks, traced from jpg map of routes (Christchurch Adventure park, 2016), and the Ohinetahi walking tracks traced from pdf map (Summit Road Society, 2017d)</i> - <i>Reserves and parks shown as broader recreation areas (Canterbury maps, 2017)</i> 	<ul style="list-style-type: none"> - <i>Depicted through current track network as depicted through NZ Track Centrelines (LINZ, 2018) , with the additional Adventure Park tracks, traced from jpg map of routes (Christchurch Adventure park, 2016), and the Ohinetahi walking tracks traced from pdf map (Summit Road Society, 2017d)</i> - <i>Reserves and parks shown as broader recreation areas (Canterbury maps, 2017)</i> - <i>Imagined extension of track networks along ridge and several in expanded native areas in South West.</i> 	<ul style="list-style-type: none"> - <i>Depicted through current track network as depicted through NZ Track Centrelines (LINZ, 2018) , with the additional Adventure Park tracks, traced from jpg map of routes (Christchurch Adventure park, 2016), and the Ohinetahi walking tracks traced from pdf map (Summit Road Society, 2017d)</i> - <i>Reserves and parks shown as broader recreation areas (Canterbury maps, 2017).</i> - <i>Buffer tracks through fuel loaded areas.</i>
Water networks	Gradually expand to cater for increased demand, and restore natural waterways	Strengthen water outlooks, and restore natural waterways	Expand network of accessible water sources, and restore natural waterways
	<ul style="list-style-type: none"> - <i>Not shown on alternative future map, though clearly depicted in trajectory maps.</i> 	<ul style="list-style-type: none"> - <i>Not shown on alternative future map, though clearly depicted in trajectory maps.</i> 	<ul style="list-style-type: none"> - <i>Not shown on alternative future map, though clearly depicted in trajectory maps.</i>
Rural pastoral	Gradual retreat from marginal areas	Retreat from marginal areas, and repurpose as native revegetation	Retreat from marginalised areas, and manage
	<ul style="list-style-type: none"> - <i>Shown with 2014 CCC farmland land use (Christchurch City Council, 2014), excluding areas</i> 	<ul style="list-style-type: none"> - <i>Shown with 2014 CCC farmland land use (Christchurch City Council, 2014), excluding areas</i> 	<ul style="list-style-type: none"> - <i>Shown with 2014 CCC farmland land use (Christchurch City Council, 2014), excluding areas</i>

	<i>shown as - 'Grassland with woody biomass' or forestry (LUCAS landcover database, 2014)</i>	<i>shown as - 'Grassland with woody biomass' or (LUCAS landcover database, 2014)</i>	<i>shown as - 'Grassland with woody biomass' (LUCAS landcover database, 2014)</i>
Exotic plantations	Restore and expand, especially south of Dyers Pass Road	Retreat and generally prohibit	Retreat from burnt areas and buffer from urban edge
	<p><i>- Shows restoration of burnt Pine plantations with full extent of forestry from 2014 CCC land use map (D. Hogan, 2014), excluding more northern, Dyers Pass road side of the Adventure Park.</i></p> <p><i>- Following southern trajectory, shows expanded exotic forestry in properties (cadastral map (LINZ, 2011) with more than 50% 'Grassland with woody biomass' (LUCAS land cover database, 2014).</i></p>	<p><i>- Depicted though current forestry extents according to 2014 CCC landuse map (D. Hogan, 2014), excluding any areas burnt in the 2017 Port Hills Fires (Jack, 2017).</i></p>	<p><i>- Depicted though current forestry extents according to 2014 CCC landuse map (D. Hogan, 2014), excluding any areas burnt in the 2017 Port Hills Fires (Jack, 2017), and any areas set out as buffers from other land uses.</i></p>
Indigenous revegetation	Protect and incrementally expand	Extensive expansion of southwest native forest-cover, and in eastern valleys	Create network of broadleaf greenbelts with general revegetation
	<p><i>- Depicted through the assumed indigenous revegetation of Reserves, and conservation land use (CCC, 2016); this (along with current indigenous forest) forms approximately 25% of the site with 22% expected (Christchurch city Council, 2008b).</i></p> <p><i>- Based on current trends, would follow a patch planting and succession method revegetation.</i></p> <p><i>- Indigenous native vegetation depicted by 'Natural Forest' (LUCAS land cover database, 2014)</i></p> <p><i>- Depicted with native revegetation of the south facing, Dyers Pass road side of the Adventure Park (Jack, 2017).</i></p>	<p><i>- Depicted through assumed native revegetation of reserves, and conservation land use (CCC, 2016).</i></p> <p><i>- Native revegetation of marginalised grasslands, as mapped by LUCAS land cover database, 2014 as 'Grassland with woody biomass', particularly affecting the south-west of the case-study.</i></p> <p><i>- Indigenous native vegetation depicted by 'Natural Forest' (LUCAS land cover database, 2014).</i></p> <p><i>- Native revegetation of Forestry areas burnt by the 2017 Port Hills Fires (Jack, 2017), covering much of the south western mid-flanks.</i></p>	<p><i>- Depicted through assumed native revegetation of reserves, and conservation land uses (CCC, 2016).</i></p> <p><i>- Native revegetation of marginalised grasslands, as mapped by LUCAS landcover database, 2014 as 'Grassland with woody biomass', particularly affecting the south-west of the case-study.</i></p> <p><i>- Indigenous native vegetation depicted by 'Natural Forest' (LUCAS land cover database, 2014).</i></p> <p><i>- Native revegetation of Forestry areas burnt by the 2017 Port Hills Fires (Jack, 2017), covering much of the south western mid-flank.</i></p> <p><i>- Any areas of native revegetation within buffer areas are to be highly-managed fire resilient broadleaf natives (greenbelt effect).</i></p>
Base map sources	<i>Contours (LINZ, 2018), Road Centrelines (LINZ, 2018), Building footprints (LINZ, 2018), Base imagery (Google maps, 2017)</i>		